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ABSTRACT

This study conceptualizes the Research and Development (R&D) organizational unit as an information processing system which, to be most effective, must respond to the changing information requirements encountered in proceeding from a research orientation (information generation and expansion) to a product or system development emphasis (information application). To contend with and reduce the level of uncertainty, a unit must process information from various sources for its problem solving or decision making activities. This approach suggests that those units matching their information processing capabilities to the information processing requirements should be effective.

The intent of this research is to investigate the information processing model of organizational design within an R&D setting. Specifically, the research will examine if perceived information requirements differ between research units and development units. Also investigated is whether some organizational designs are more effective than others in meeting a unit's information needs. If these propositions are substantiated, an organizational contingency approach for R&D project management would be supported, in addition to providing empirical research assessing the information processing approach to organizational design and effectiveness. Implications could then be drawn for organizational unit design and the design of computer-based information systems.

xx

ORGANIZATIONS AND INFORMATION PROCESSING: A FIELD STUDY OF
RESEARCH AND DEVELOPMENT UNITS WITHIN THE UNITED STATES AIR FORCE
SYSTEMS COMMAND

by

Thomas Triscari, Jr.

A Thesis Submitted to the Graduate Faculty of
Rensselaer Polytechnic Institute in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Management

Approved by the
Examining Committee:

William A. Wallace, Thesis Advisor

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Rensselaer Polytechnic Institute
Troy, New York

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August 1984

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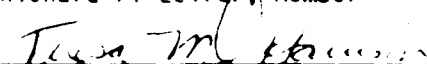I would like to take this opportunity to express my sincere appreciation to the many individuals that contributed to and supported this study.

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ABSTRACT

This study conceptualizes the Research and Development (R&D) organizational unit as an information processing system which, to be most effective, must respond to the changing information requirements encountered in proceeding from a research orientation (information generation and expansion) to a product or system development emphasis (information application). To contend with and reduce the level of uncertainty, a unit must process information from various sources for its problem solving or decision making activities. This approach suggests that those units matching their information processing capabilities to the information processing requirements should be effective.

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CHAPTER 1

INTRODUCTION

1.1 Background

The process of design, development and manufacture of new "high technology" products is becoming increasingly complex as pressures for increased productivity mount and product life cycles decrease. These pressures are also felt by the Department of Defense Research and Development community where the length of weapon system operational (useful) life times are decreasing and development costs and times for new, more technologically sophisticated systems are increasing (Underwood and Zabeski, 1983). The recent renewed emphasis on developing high technology industries' ability to obtain and maintain competitive advantage within both the military and commercial sectors suggests that the management of Research and Development (R&D) activities remains a vitally important topic to practitioners and researchers. The management process employed to develop and convert new technologies into products and operating systems requires the coordination and integration of resources and activities from multiple sources and disciplines. This difficult task of managing a variety of specialists from different functional disciplines has resulted in the development and implementation of the project or program management

concept of organizing for product or system innovation.[1] The importance of effective R&D management is accentuated by several studies demonstrating that nontechnical factors, often organizational in nature, are critical barriers to achieving successful innovation (Twiss, 1980). The apparent heavy mortality rate of industrial R&D projects attributed to nontechnical factors, estimated by Abetti (1983) to be nearly 2 out of every 3 failures, provides further incentive for the study of R&D management processes.

Although the site for this field investigation is within a military R&D setting, the scope of the research is broader in the sense that the research questions to be examined in this research are essentially derived from the relationships within the information processing model of organization design. Hence, this research involves, in addition to the study of R&D work groups, an examination of the information processing approach to organizational design. Empirical research published in the literature and reviewed in Chapter 2, has provided evidence that portions of this model are valid. That

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[1] The distinction made between a project and a program is one of scale or magnitude of effort. Cleland and King (1975) state that programs are "generally larger and more directly related to the basic organizational objectives than are projects. Any one program of an organization might be composed of many different projects which in sum will aid in achieving a specific output oriented objective of the organization." Programs may also be open-ended in nature, while projects have more specific objectives and end-points.

is, a significant amount of research in contingency theory has shown that relationships exist between the contextual variables of technology, environment, size, and perceived uncertainty (information processing requirements). Other research, though less empirically oriented, has indicated that the organizational structure and inter-unit coordinating mechanisms influence organizational information flow or communication (information processing capabilities). However, there have been few studies that attempt to empirically examine the overall information processing approach to organizational design as proposed by Tushman and Nadler (1978, 1980). The results from the few studies empirically examining this model have been inconclusive, calling for additional research. Kmetz (1981), in an aggregate study comparing four models of organizational structure found a significant relationship between information processing variables and effectiveness. Kmetz, however, suggests that more attention needs to be directed toward verifying the information processing approach. Morrow (1981), in failing to find a significant relation between the information processing (communication) variables and unit effectiveness, calls for more empirical research citing a need for greater specificity and elaboration in the study design.

Regardless of the limited empirical attention, the information processing approach provides a potentially powerful and much needed conceptual tool to those responsible for the design of organizations.

Computer based information technology is becoming increasingly sophisticated and available in the form of telecommunications, automated offices, electronic mail, management information systems, and decision support systems. Many organizations are beginning to introduce these "information management" systems into the work place with the intent of expanding their organizational information processing capabilities and the expectation of a big return on their investment (Olson, 1980). Unfortunately, this has not often been the case (Lucas, 1979). The strategy or rationale behind the design and implementation of these systems within the organization is often unclear. The idea that "the more information the better" seems to be the common philosophy. The recent number of articles in the literature discussing effective approaches to information system design suggests that computer based information systems are having implementation problems in the field (Mason and Mitroff, 1973; Benbasat and Taylor, 1978; King and Rodriguez, 1978; Zmud, 1979; Bariff and Lusk, 1977; Sprague, 1980; Sage 1981; Robey and Farrow, 1982; and, Benbasat and Taylor; 1982).

The extent to which the technologies of the "information age" will improve (or impede) an organization's performance will depend largely on the degree of knowledge or understanding of the organizational information processing needs. Then, and only then, can the appropriate information processing activities be facilitated by

applying this technology. Galbraith's (1971) view of organizations as information processing systems seems to offer a promising conceptual staging point for examining the relationship between organizational design and information technology. However, additional empirical investigations of the information processing model, leading to a better understanding of organizational information systems, seem to be desirable before making additional prescriptive statements concerning the design of organizational information systems. This research is intended to contribute to this cause.

1.2 Research Objectives

Although substantial research has been conducted to identify the relationship between an R&D unit's communication activities and project performance, the results have been inconsistent (Johnston and Gibbons, 1975 and; Pruthi and Nagpaul, 1978). The broad range of activities that is typically associated with the Research and Development function may have been a factor confounding this research. A recent study by Allen, Lee, and Tushman (1980) found that certain communication patterns were effective for some R&D groups and ineffective for others based on the nature or type of work being conducted by a particular group. That is, effective research-oriented units had communications patterns that differ from effective development-oriented groups. Apparently, communication or information

needs change with differences in the nature of the R&D task. These results support a contingency approach to the design of R&D organizational information systems.

There exists, however, little empirical research that specifically examines those factors affecting the R&D units information needs throughout the R&D process. Likewise, few studies have been performed investigating those factors under management's influence that effect a unit's communication or information flow pattern. Hence, a need remains to identify and empirically investigate the basis for organizing the R&D function. Galbraith's (1971) conceptualization of the organization as an information processing system, further refined by Tushman and Nadler (1978, 1980), provides a theoretical foundation for conducting such research.

Galbraith (1971) states in order to manage the organization (that is, to organize plan, coordinate and control activities; interpret the external environment; handle problems or make decisions), members attend meetings, send and receive reports, obtain knowledge of events relevant to performance, read printouts, and, perhaps, disseminate instructions. All of these activities involve the processing of information within the organization in some form.

Tushman and Nadler (1978) propose a model which states that, to be effective, an organization's design must attend to the dynamics of task-related uncertainty through patterns of technical communication

and information flow. This model further identifies factors impacting an organizational units information needs as well as those factors influencing the units communication or information processing behavior.

The major purpose in conducting this research is to assess the validity of the information processing model of organizational unit design within the context of the United States Air Force (USAF) R&D community. More specifically, the objectives of this research are to:

1. determine if information processing requirements differ between research and development;

2. examine those contextual factors thought to influence a unit's information needs or requirements;

3. examine those organizational factors thought to influence a unit's information processing capabilities; and

4. to test if matching information processing capabilities to requirements results in effective unit performance.

1.3 Definitions of Key Terms

Organizational researchers have devoted considerable effort to identifying those variables that influence organizational design. The premise being that by designing the organization "appropriately" organizational effectiveness will be enhanced. Unfortunately, progress toward this goal has been restrained by the complexity of the task. The complexity of this task has contributed to difficulties in defining key concepts as well as creating methodological problems. This section provides definitions to several key concepts and terms

used in this research, with the intent of establishing reference points for this investigation.

For purposes of this research, organization design refers to the organizational unit structure and the integrating mechanisms used to coordinate the various activities of organizational units. Duncan (1973) defines an organizational unit as a formally specified work group within the organization under a superior charged with a formally defined set of responsibilities directed toward the attainment of the goals of the organization. The organizational unit will be the "unit of analysis" in this study.

The concept of organizational effectiveness, although a central concept in organizational theory, has not been well developed nor has there been agreement upon factors which determine it (Quinn & Cameron, 1983). A variety of models and indicators of effectiveness have been developed by researchers (Campell, 1974) and debates about the superiority of one model over another continue to be found in the literature (Price, 1972; Molnar & Rogers, 1976; and Strasser, 1979). Recent research suggests that organizational effectiveness is a multi-dimensional concept associated with the multiple constituencies involved with the organization (Connolly, Conlon and Deutsch, 1980). Quinn and Cameron suggest that changes in the dominance of the various constituencies over the life of an organization may require it to adopt the primary criteria of the dominant constituency in order for

the organization to survive. Steers (1975) identified general categories of organizational effectiveness: goal achievement; integration; and adaptaility. Mott (1972) validated the following dimensions and measures of effectiveness for several federal government organizations: productivity; adaptability; and anticipation of problems. Katz and Tushman (1979), in evaluating project performance, used the following items to measure of performance: schedule, cost, innovativeness, adaptability and cooperation. In terms of evaluating the performance of USAF R&D units, Brabson (1982) suggests that a mixture of quantitative and qualitative measures be used. Brabson identified the following as important, "quantifiabale" measures of an R&D unit's performance: the units ability to maintain technical, cost and schedule goals.

Similarly, researchers have had difficulty establishing the elements or dimensions of organization structure. The construct of organizational structure is commonly defined as representing the patterns and relationships that exist within organizations or work unit elements (Blackburn, 1982). Although, as Blackburn points out, the conceptualization of structure as multidimensional is generally well accepted, an examination of the literature reveals a lack of convergence on the specific dimensions. For example, Pugh, Hickson, Hinings and Turner (1968) suggest four dimensions of structure, Champion (1975) suggests three, James and Jones (1976) propose seven, and Montanari (1978) identifies 16 possible dimensions of structure.

Three of the most common dimensions of organizational structure, defined by Pugh, Hickson, Hinings and Turner (1968) are formalization (the extent to which rules, procedures, instructions and communications are written), specialization (the division of labor within the organization, the distribution of official duties among a number of positions) and centralization (the location of authority to make legimate decisions that affect the crganization).

1.4 Organization of the Thesis

Chapter 2 presents a review of theory and models relevant to this research. A brief discussion is presented of the USAF R&D process which divides the project's or system's life cycle into several stages or phases. A summary is made of the activities and decisions involved in each of these stages A review of the contingency approach to organizational design provides a basis for a detailed discussion of the information processing model which underlies this research.

Chapter 3 presents the hypotheses to be examined in this research. Four major sets of hypotheses are presented, each directly related to the basic foundations of the information processing model of organizational design.

The methodology devised to evaluate the hypotheses of Chapter 3 is discussed in Chapter 4. The statistical approach, sample population, and measurement instruments are discussed.

Chapter 5 presents the statistical evidence used in evaluating each of the hypotheses proposed in Chapter 3. The adequacy of the information processing, as proposed by Tushman and Nadler (1978), within this field setting is examined in Chapter 6 using a path analysis technique. The path analysis technique itself is discussed in Appendix D.

An alternative information processing formulation is developed and discussed in Chapter 7, providing insight into the relationships found within the data.

Chapter 8 interprets the results and discusses the implications of this study for R&D organizational information systems.

CHAPTER 2

LITERATURE REVIEW

2.1 Communication in R&D Organizations

A key area of research in R&D organizations has focused on describing and assessing the communication or information flow patterns of R&D personnel (Epton, 1981). The reason for such emphasis is that throughout the entire R&D process, from recognition of technical feasibility to technology transfer, ideas and knowledge are developed and evaluated by the project organization through information processing activities (Fischer, 1980). One of the most published findings in this area was the identification by Allen (1966) of a "technological gatekeeper" who served the organization's information processing needs by performing as a transfer mechanism in a multi stage communication process, specifically between R&D laboratory personnel and various external information sources. That is, the technological gatekeeper played a key role in the organization by providing outside technical information, often critical to the innovation process, to other R&D project members. Since Allen's work, researchers have identified a host of other functions performed by the gatekeeper including: a filter or screener of information (Garvey & Griffith, 1967); an internal consultant on technical matters (Allen & Cohen, 1969, and Allen, 1970); and, a facilitator of external

communication of more locally oriented project personnel (Tushman & Katz, 1980).

A number of studies have described the role of the technological gatekeeper as well as the existance of other types of gatekeepers, such as those in marketing and manufacturing (Holland, 1976). Moreover, several researchers have attempted to quantitatively assess the effectiveness of the technological gatekeeper within the organization (Ritchie, 1977 and Delehanty, Sullo & Wallace, 1982). However, the importance of this research to the practicing R&D manager revolves around the premise that "improved" organizational communication or information flow will positively affect project performance. That is, since improved information flow should enchance knowledge about the state of the technology, the external environment, or what the organization as a whole is doing, better project performance should result. Conrath (1973) suggests that not only should individuals be responsible for gathering or bringing in information but that organizational units be designated explicitly for the processing of information. Thus, the R&D organizational unit must not rely solely on gatekeepers or boundary spanners to bring in extra unit information but should be designed in a way that facilitates the processing of information required to perform it's function.

Until recently, little empirical research has been undertaken to assess the relationship between an R&D unit's organizational design, information flow, and performance (Epton, 1981). Much of the research performed has been descriptive in nature, emphasizing the identification of gatekeepers within various R&D settings. These results themselves have not been totally consistent (e.g., Johnston and Gibbsons, 1975 and Pruthi and Nagpaul, 1978). Research by Allen, Tushman, and Lee (1979, 1980) explains why the existance of technological gatekeepers may vary within R&D settings. Since R&D in many firms encompasses a wide variety of activities ranging from idea generation and conceptualization to engineering design and system testing, the information requirements will differ for each specific activity. Specifically, Allen, Tushman and Lee concluded that, to be effective, research-oriented units require extensive external information processing activities (i.e., many boundary spanning roles are required) in order to obtain the "state-of-the-art" or "cutting edge" in technological knowledge. The emphasis in these R&D units is on technology expansion and to perform this activity it is necessary to have strong extra-unit and extra-organizational contacts. However, for those units responsible for the development-oriented activities, Allen, Tushman and Lee found a negative relationship between technological gatekeeping and unit performance. One possible explanation for this relationship may be

the undesirable changes to an established design specification typically brought about by "newly discovered" information. Although these changes may be improvements to the technical performance, the emphasis of this R&D activity is on product or system development. The performance or effectiveness criteria in system development include strict cost and schedule parameters. Technical improvements to the system design, over and above that required by the specifications, typically affect cost and schedule constraints negatively (this practice is often referred to as "gold plating"). The implication here for management is to reduce the temptation to continually upgrade the technology in a system by "limiting or discouraging" the import of undesirable technical information into the unit and by reinforcing the notion that the design must be a balanced tradeoff among technical, cost, and schedule parameters.

The research results of Allen, Tushman and Lee tend to support a contingency approach to the design of R&D organizational information systems. The relationship between organizational design and communication patterns or information flow within an R&D unit throughout the R&D process has not received much empirical attention. There has, however, been general field research examining the relationships between level of organizational uncertainty, a concept related to information need, and organizational structure and design (e.g., Duncan, 1973; Huber, O'Connel, and Cummings, 1975; Leifer and

Huber, 1977; Kmetz, 1981; Morrow, 1981; and McDonough and Leifer, 1983). This literature generally supports the notion that higher levels of uncertainty require greater information needs for effective decision making or problem solving, and that organizational structures vary due to information processing or communication patterns.

The results of this research suggest that a unit's information needs are determined from the uncertainty it faces. Furthermore, the communication behavior of a unit is influenced by its organizational design. Since R&D is generally considered a uncertainty reduction process (Archibald, 1976), an implication is that information needs change, hence, a corresponding change in organizational unit design may be necessary. That is, a unit organizational development approach to R&D project management may lead to more effective and efficient resource utilization and performance.

The next sections review first the phase model approach to the R&D process, and then the contingency and information processing models of organizational design.

2.2 The R&D Process

Research and development can be viewed as a conversion process concerned with the transformation of inputs (e.g., scientific knowledge, materials, and customer needs) into outputs or products (e.g., new knowledge techniques or systems) (Twiss, 1981). The

phase process model of R&D focuses on the level of uncertainty associated with an activity and on the extent to which the activity is directed toward specific organizational objectives. R&D projects typically undergo a distinct life cycle of development in which each phase of the cycle requires different levels and varieties of specific thought and action performed by the organization (Cleland and King, 1975). With the completion of each succeeding life-cycle phase the uncertainty associated with a project's ultimate technical, time, and cost performance is reduced (Archibald, 1976) Along with a reduction in uncertainty, Abel (1977) concludes that the information requirements change also.

Over the last twenty years, many models have been proposed in an attempt to specify the various stages or phases involved in the R&D process (e.g. Karger and Murdick, 1963; Myers & Marquis, 1969; Sayles & Chandler, 1971; Utterback, 1971; Cleland & King, 1975; Thamhain & Wilemon, 1975; Archibald, 1976; Cleland and Kocaoglu, 1981; Twiss, 1981; Cooper, 1983 and Tornatzky, et. al, 1983). A primary motivation behind these models is to provide a better understanding of the process and to offer managers insight as to how they may better control or influence the outcome.

Cleland and Kocaoglu (1981) suggest that the use of the phase approach to R&D provides the following benefits to management:

> enforces a proactive approach to the planning and control of
> of project activities; and

> provides natural check points or milestones for the review
> and assessment of work progress and viability.

The phase model approach to R&D or engineering project management
has been widely applied within the government and private industry.
This thesis proposes that the R&D process can be viewed as consisting
of two major sub-processes, each having several distinct phases.
These subprocesses, differentiated by the nature or purpose of the
work performed, are technology expansion and systems development.[2]
Technology expansion is primarily concerned with expanding scientific
knowledge and generally assessing it's feasibility. In this sense,
technology development places an emphasis on the inventive process,
that is, expansion of a technology base. Systems development involves
the application of the technology base to operational requirements
with the intent of bringing a new (or modified) product or weapon
system into existence (innovation oriented).

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[2] These two terms correspond to Research and Development activities
respectively. The term R&D has become so widely used that the
distinction between Research and Development activities has
become blurred. Indeed, it is the intent of this research to
identify the differences between these activities in terms of
information requirements. The use of these terms is intended to
aid in this purpose.

The Air Force Systems Command (AFSC), responsible for conducting USAF R&D activities, employs a phase process approach to R&D project management. Viewing the R&D process in terms of the technology expansion and systems development categories is particularly appropriate in the AFSC context since two organizational entities have been established within the Command to perform these activities. The AFSC Laboratories are responsible for the technology expansion activities and the AFSC Product Divisions are responsible for system development activities. In addition, the phase process mode of R&D management used by the AFSC has been institutionalized in many of the private contractors working under USAF R&D contracts. Hence, the phase approach to the R&D process is not just a conceptual model but is a widely accepted and practiced procedure that is followed in the field.

The work performed within the technology expansion subprocess are categorized into 4 major areas, primarily used for budgeting purposes. However, these categories of activities also correspond to a phase or life cycle approach to technology expansion. The four phases are formally known as Basic Research, Exploratory Development, Advanced Development and Engineering Development. Basic Research involves those activities which extend the boundaries of knowledge without any specific technical objectives in view. Exploratory Development seeks new knowledge having specific technical application

and the creation and testing of radically new concepts or components. This phase does not involve those activities associated with development for operational use. Advanced Development begins with a concept which has been shown to be technically feasible but which requires further change due to user needs. It involves testing new components and subsystems within a laboratory environment into an overall system design, with hardware developed typically taking the form of a prototype system (such as a bench model).

These activities, as a whole, seem to advance the state of knowledge concerning a technology in a systematic way. Hence, viewing these activities as phases contributing to the technology expansion process seems logical. However, R&D personnel do not readily think of these activities personnel, as belonging to a phase model process. One explanation for this may be the relatively long period of time (several years or a decade) required to move a technology from phase to phase (e.g., from exploratory development to advanced development) as opposed to the period of time to move a project from phase to phase in system development (seldom more than 2 or 3 of years). Indeed, some researchers may devote a large portion of their careers on one technology project without the work ever progressing to the next phase. Another reason for reluctance to view the technology expansion activities as a phase process may be the high attrition rates of projects. That is, the nature of these activities, which is to

determine the feasibility of a technological development, may result in a decision of infeasibility (for technical or non technical reasons). Hence, the work or project does not progress to the next phase of technology development but gets "put on the back burner" (i.e., remains in its present state for further or later development, but at a lower level of intensity) or at worst, gets terminated. Nevertheless, the technologies associated with these projects within the system development process have gone through an intensive and extensive development cycle. Despite the fact that these activities or phases may have taken many years, even decades, and may have been worked and built upon by various researchers or laboratories, the technology was developed from a succession of activities, that is, a process.

The system development process within AFSC, termed the Weapon System Acquisition Process (WASP) with AFSC, is divided into five major phases distinguished from each other by the unique objectives and task characteristics of each phase (Noyes & Parker, 1979). For major programs, each phase begins with a required program decision (milestone) which is generally made by the Defense System Acquisition Review Council (DSARC) and ratified by the Secretary of Defense. The five phases are termed conceptual, demonstration/validation, full scale development, production, and deployment. The milestones that initiate each respective phase are labelled 0, I, II, and III (Figure 2.1).

FIGURE 2.1

PHASES OF THE WEAPON SYSTEM ACQUISITION PROCESS

MILESTONE 0   MILESTONE I   MILESTONE II   MILESTONE III

CONCEPTUAL   DEMONSTRATION VALIDATION   FULL SCALE DEVELOPMENT   PRODUCTION   DEPLOYMENT

Conceptual Phase — Technical, military, and economic bases are established, and the management system is set, acquisition strategy are delineated (determine to limit feasibility, tradeoffs, typing operational requirements.

Demonstration and Validation Phase — Major program characteristics are validated and refined, program risks are identified, resolved, or minimized.

Full Scale Development Phase — Designs, fabrication and test are complete.

Production Phase — The system is efficiently produced and delivered as an effective supportable system. Management responsibility of program shifts to Air force logistics command.

Deployment Phase — The system reaches its operational ready state and is turned over to the user customer.

A continuing analysis of existing capabilities and potential threats (or opportunities) is made by all DOD Agencies, and when a need or opportunity is identified a Mission Element Need Statement (MENS) is prepared. The MENS discusses the mission purpose, capability, agencies involved, time constraints, relative priority, and operating constraints, but does not specify the system, equipment or materials which might satisfy the need (Connors & Maloney, 1979). In the conceptual phase the following major activities take place: the technical, military, and economic bases are established, the management approach and acquisition strategy are delineated; and the identification and selection of the system concepts that warrant further development are made. In the validation phase, major project characteristics are validated and refined, technical cost and schedule risks are assessed, resolved, or minimized. Full-scale development involves the design, fabrication, and testing of an operational system prototype. These first three areas constitute what I will consider as the ystem development process, since the production phase is associated with efficiently producing the system, while the deployment stage involves activities concerned with delivering an operational system to the user (customer).

Holtz (1969) suggests that the most significant charactersitic of the system development process appears to be the type of work performed in each phase. In the conceptual, demonstration and

validation phases, the tasks are theoretical and widely varied. During the full scale development phase, activities become more structured and somewhat more repetitive. Most of the technical uncertainty should have been resolved upon entry into the production phase in which the technical tasks become highly repetitive and routine.

Salyes and Chandler (1971) state that organizational changes can be expected when a system progresses from one phase to the next. They conclude that the management control system must be capable of dealing with the technical uncertainties, the changing number and importance of interest groups, the continual discovery of new designs and facts, and changing constraints and pressures. Noyes and Parker (1978) suggest that such changes in tasks and organizational players would have a considerable impact on the R&D units' organizational design.

Figure 2.2 summarizes this section by presenting a phase Model approach of the AFSC R&D process. In terms of this research, the importance of this model is to demonstrate that R&D is a uncertainty reduction process imposing different requirements on the organization. The R&D process consists of two major subprocesses: technology expansion and system development. These subprocesses themselves are further broken down into several distinct phases. The intention of each phase activities is to reduce incrementally the uncertainty associated with developing a technology into an operational system.

FIGURE 2.2

A PHASE MODEL APPROACH TO THE USAF R&D PROCESS

| BASIC RESEARCH | EXPLORATORY DEVELOPMENT | ADVANCED DEVELOPMENT | ENGINEERING DEVELOPMENT | CONCEPTUAL | VALIDATION | FULL SCALE DEVELOPMENT |

TECHNOLOGY DEVELOPMENT

SYSTEMS DEVELOPMENT

PURPOSE

EMPHASIS: INVENTION — INNOVATION

OBTAINED FROM: INFORMATION/KNOWLEDGE GENERATION — INFORMATION/KNOWLEDGE APPLICATION
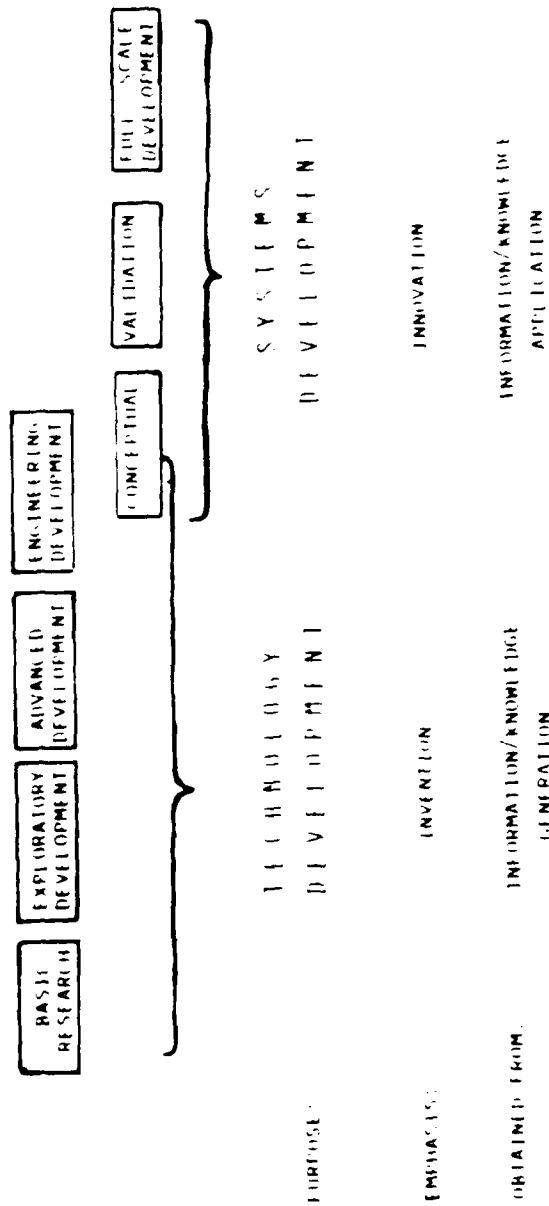
2.3. Organization Design

2.3.1. Contingency Approaches to Organization Design

A significant amount of research effort has been expended in conceptualizing and empirically determining the key variables that determine if an organization's structure is contextually appropriate. Contingency theory suggests that the degree of organization effectiveness depends largely on how well the organizational structure can be matched to the so called contextual variables. Size, technology and environment are three contextual variables which have been the subject of most research efforts (Ford & Slocum, 1977). The contextual variables form the foundation of many of the current contingency theory models of organization design. Figure 2.3 presents a model in which size, technology and environment are proposed as being the most important determinants of organization structure which, in turn, impacts organizational effectiveness (Montarari, 1978).

Since these contextual variables are believed to have an important influence on effective organization structure an examination of each variable is provided. A review of these factors will provide the foundation for and offer insight into the development of the information processing approach to organization design.

FIGURE 2.3

CONCEPTUAL MODEL OF ORGANIZATIONAL DESIGN
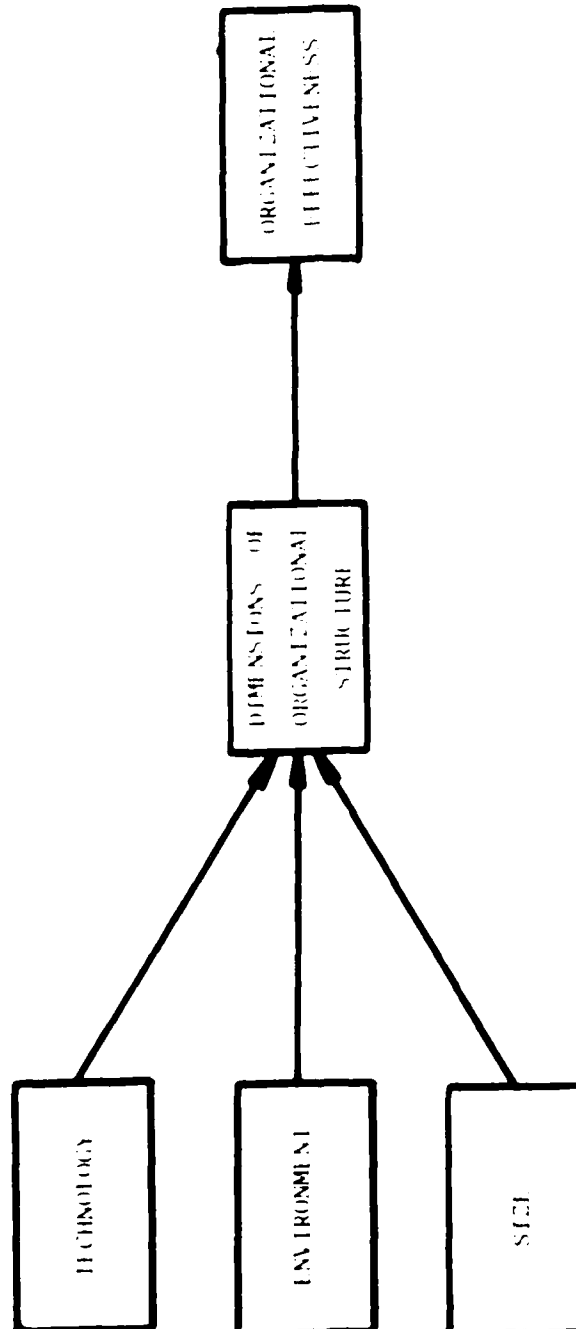
2.3.1.1 Technological Imperative

Technology is commonly defined by organizational researchers as the process of transforming inputs into outputs. However, the process of transforming inputs into outputs is concerned with more than simply the hardware of production systems or operations. An organization's technology represents a sequence of events that involve the acquisition and admission of input (raw materials, people, information) into the organization, transformation of this input into output (products or services) through the abilities and capabilities of both operators and equipment, and disposal of output into the environment (Rousseau, 1979).

Previous research into the technology-organization interaction has led to the now outdated concept of the "technological imperative". That is, there was one and only one way to operate a technology efficiently and effectively, and this usually involved one basic organizational design - a structured, hierarchical, bureaucratic model (Taylor, 1947, Koontz and O'Donnell, 1955). Technology was presumed to require a "Weberian" or mechanistic organization (Mooney and Reilly, 1939).

During the 1960's several empirical studies were performed that examined organizations as aggregate units. Burns and Stalker (1961) in examining 70 case studies on British and Scottish manufacturing firms identified two types of organizations: mechanistic and

organic. The mechanistic organization was characterized by well defined responsibilities, relationships, and hierarchy of authority as well as formal (written) rules and procedures. In contrast, the organic form of organization had unspecified responsibilities and authorities, few rules and information flowed in all directions. The principal finding of the study was that the mechanistic form was effective for stable technology and markets, while the organic organization seemed most effective in markets characterized by rapid changes in products and technology.

Woodward (1965) studied 100 English manufacturing firms specifically with respect to the type of production process used by the firm. The organizations were ranked on a scale of increasing technological compexity which also characterized the predictability and controlability of the process. Job shops producing small batches to customer order were on the low end of the scale; large batch, assembly processes in the middle range; and, continuous process industries constituted the high end. Consistent with the Burn and Stalker study, Woodward found that the organization form varied with the production process. In addition, certain forms were discovered to be more effective than others for a particular production process.

Perrow (1965) conceptualized organizations in terms of their technologies, specifically by examining two aspects or dimensions of a task that he claimed were independent; the number of expections that

must be handled (few or many) and the degree to which search is an analyzable or unanalyzable/intuitive procedure. Perrow defines a nonroutine task or technology as having a large number of exceptions and a search which is not logical or analytic. With non-routine tasks there are few well established techniques; there is little certainty about the methods used, or whether or not they will work. Non-routine also means that there may be a variety of different tasks to perform, in the sense that raw mater als are not standardized or orders for customers ask for many different or custom made products (Perrow, 1970). Few exceptions and analyzable search procedures describe a routine technology. With routine tasks there are well established techniques which are sure to work and these are applied to essentially similar raw materials. There is little uncertainty about methods and little variety or change in the tasks that must be performed. These tasks might be associated with a highly standardized production operation. Two other technology types result from other combinations

craft (few exceptions, not analyzable) and engineering (many exceptions, analyzable) technologies. Figure 2.4 depicts a four-fold table that represents the Perrow technology framework for the comparative analysis of organizations. Perrow's two dimensions are often combined into a undimensional continuum representing the degree to which an organization's technology is routine (illustrated by the diagonal in Figure 2.4).

FIGURE 2.3

PERROW'S 1967 FRAMEWORK FOR CATEGORIZING ORGANIZATIONAL TECHNOLOGY

ANALYZABILITY
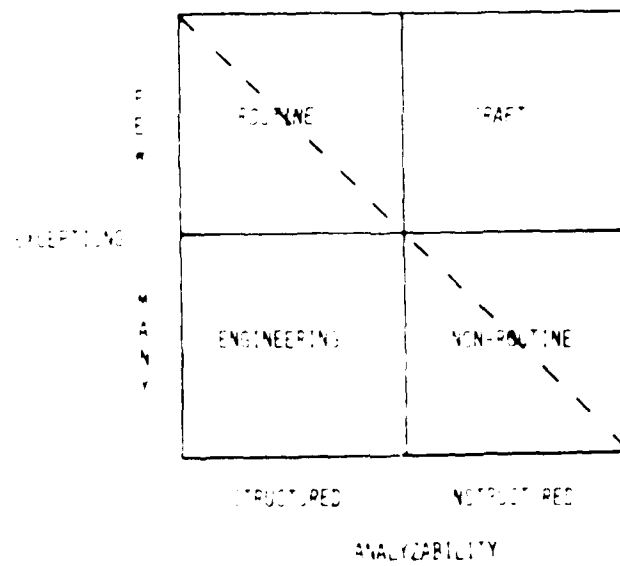
2.3.1.2   Environmental Factors

An organization exists within a larger, and to some degree,
uncontrollable environment. In order for an organization to survive,
it must attend to the environmental forces of competitors, government,
environmentalists, etc. Emery and Trist (1965) were of the first
researchers to conceptualize the differing causal textures of
organizational environments. They offered a typology which identifies
four "ideal types" of environments, approximations to which exist
simultaneously in the "real world" of most organizations, though their
weighting will vary from case to case. The simplest type is called
the placid, randomized environment in which goals are relatively
unchanging in themselves and randomly distributed. The economist's
classical market corresponds to this environment. Organizations under
these conditions can exist adaptively as single and quite small
units. A more complicated environment is the placid, clustered one in
which goals are relatively unchanging in themselves but are
clustered. This environment corresponds to the economist's "imperfect
competition." The third ideal type is termed the disturbed-reactive
environment in which there is more than one organization of the same
kind. The economist's oligopolic market corresponds to this type of
environment. The fourth type and most complex environments are called
turbulent fields. The distinction between types 3 and 4 is that the
dynamic properties in type 4 arise not only from the interaction of

the component organizations, but from the field itself.

Environments can be conceptualized as ranging from relative certainty (certainty regarding both cause-effect relationships as well as the outcomes of decisions) to relative uncertainty (where there is uncertainty about cause-effect relationships and the outcomes of decisions). Terreberry (1968) elaborates on the description of the turbulent field environment as being

...characterized by complexity as well as rapidity of change in the environment.

and where

...the accelerating rate and complexity of interactive effects exceeds the component systems capacities for pre-diction and, hence, control of the compounding consequences of their actions.

Duncan (1972) characterized organizational environments by two continuum or dimensions: a simple-complex dimension and a static-dynamic dimension. The number of factors taken into consideration in decision making defines the simple-complex dimension, while the static-dynamic dimension is viewed as the degree to which the factors involved in decision making change. As demonstrated by Duncan's work, the central concept underlying the impact of environmental forces on organizational variables is uncertainty (Downey, Hellriegel and Slocum, 1975). Downey and Slocum (1975) conceptualize uncertainty as a psychological state in which the sources of variability stem from an individual's cognitive

processes, variety of experience, and social expectations as well as environmental attributes. Indeed, Duncan defines environmental uncertainty and the environmental dimensions in terms of the perception of organization members, hence we are actually concerned with perceived environment uncertainty.

Combining the two environmental dimensions identified by Duncan (i.e., complexity and dynamism) gives a undimensional continuum ranging from a relatively certain (simple, static) environment to a relatively uncertain (complex dynamic) one. Figure 2.5 illustrates Duncan's framework for categorizing organizational environments and where the diagonal represents the uncertainty continum. Data from Duncan's research supported the hypothesis that individuals in decision units characterized by dynamic-complex environments experience the greatest amount of uncertainty in decision making and that the static-dynamic dimension makes the more important contribution to perceived environmental uncertainty.

FIGURE ...

DUNCAN'S (1972) FRAMEWORK FOR CATEGORIZING
ORGANIZATIONAL ENVIRONMENTS AND PERCEIVED UNCERTAINTY

	DEGREE OF COMPLEXITY	
	SIMPLE	COMPLEX
STATIC	**LOW PERCEIVED UNCERTAINTY** SMALL NUMBER OF FACTORS AND COMPONENTS IN THE ENVIRONMENT FACTORS AND COMPONENTS ARE SOMEWHAT SIMILAR TO ONE ANOTHER FACTORS AND COMPONENTS REMAIN BASICALLY THE SAME AND ARE NOT CHANGING	**MODERATELY LOW PERCEIVED UNCERTAINTY** LARGE NUMBER OF FACTORS AND COMPONENTS IN THE ENVIRONMENT FACTORS AND COMPONENTS ARE NOT SIMILAR TO ONE ANOTHER FACTORS AND COMPONENTS REMAIN BASICALLY THE SAME
DYNAMIC	**MODERATELY HIGH PERCEIVED UNCERTAINTY** SMALL NUMBER OF FACTORS AND COMPONENTS IN THE ENVIRONMENT FACTORS AND COMPONENTS ARE SOMEWHAT SIMILAR TO ONE ANOTHER FACTORS AND COMPONENTS OF THE ENVIRONMENT ARE IN A CONTINUAL PROCESS OF CHANGE	**HIGH PERCEIVED UNCERTAINTY** LARGE NUMBER OF FACTORS AND COMPONENTS IN THE ENVIRONMENT FACTORS AND COMPONENTS ARE NOT SIMILAR TO ONE ANOTHER FACTORS AND COMPONENTS OF THE ENVIRONMENT ARE IN A CONTINUAL PROCESS OF CHANGE

DEGREE OF CHANGE

2.3.1.3 Organization Size

Pugh, Hickson, Hinings and Turner (1968) were among the first researchers to extensively study the relationships between size and other organizational variables. The Pugh-Hickson research was initially a follow up to the Woodward (1980) technology studies previously discussed. The primary difference between the two research efforts was the Woodward concentrated largely on small firms, whereas Pugh and Hicksen examined a higher percentage of large sized companies. Analysis of their data led Hickson, Pugh and Pheysey (1969) to conclude:

> Structural variables will be associated with . . .
> technology only where they are centered on the work
> flow. The smaller the organization the more its
> structure will be pervaded by such technological
> effects; the larger the organization the more these
> effects will be confined to variables . . . on activities
> linked with the work flow itself, and will not be detect
> able in variables of the more remote administrative and
> hierarchial structure.

The findings imply that the effects of technology on organizational structure cannot be considered without accounting for the effects of organizational size. Pugh Hickson also found a strong correlation between size and the structuring of activities, including standardization of functions, formalization of procedures, and specialization of roles. As a result of their findings, Pugh and

Hickson hypothesized that

>An increasing scale of operations increases the
>frequency of recurrent events and the repetition of
>decisions, which are then standardized and formalized
>. . . Once the number of positions and people grow
>beyond control by personal interaction, the organization
>must be more explicitly structured.

Porter, Lawler, and Hackman (1975) state that:

>Although the available evidence... is not clear-cut about
>the relationships of size to other organizational variables,
>it does appear to point to some limited impact of size if
>(1) the range of sizes being considered is great enough and
>(2) the other variables in the relationship tend toward measures
>of bureaucratic-type operations. The direction of the relation-
>ship, where there is one, seems clear: larger size tends to be
>related to a more mechanistic, bureaucractic mode of operation.

2.3.2 Information Processing Approaches to Organizational Design

Conceptualizing organizations as information processing systems was perhaps first proposed by Galbraith (1971) and provides insight into the contingency theories previously discussed. Additional work has been done to expand this approach to organizational design (Simon, 1973; Galbraith; 1973, 1977; Tushman and Nadler, 1978). The intent of this section is to review the various components of the information processing approach to of organizational design.

Information processing consists of the search, receipt, evaluation and integration of information into an organization's decision making or problem solving processes (Cravens, 1970). Information enters from the boundary or outer skin of the organization along communication paths or networks through to the others within the organization (Leifer, 1983). In this way information can be utilized for decision making or problem solving. Information may be transmitted through different modes including verbal or written. In R&D organizations, a number of studies have demonstrated the high reliance by technical personnel on verbal communication processes including Allen and Cohen (1969), Gersteinfeld (1970), Utterback (1971) and Tushman (1977).

Information theorists have defined information as something that reduces uncertainty or entropy in a receiver (Shannon and Weaver, 1949). For Leifer (1978), Daft and Macintosh (1981), and Wildavsky (1983), among others, information is defined as usable, nonroutine,

and capable of altering a mental representation, whereas data is confirmatory in nature and does not reduce uncertainty. The importance of decision making or problem solving uncertainty derives from the limited capacity organizations have for gathering and processing information and for predicting the consequences of various decison alternatives. Under conditions of greater uncertainty, organizations must develop processes for searching, gathering, coding and communicating information to reduce the level of uncertainty in order to provide decision makers with increased "visability" into decison alternatives or outcomes. Increasing management's knowledge or information concerning the range of feasible alternatives or possible outcomes reduces the level of uncertainty and allows the decision choice to be more accurate. Since information has the quality of reducing uncertainty, organizations faced with higher levels of uncertainty are expected to need increased information processing capabilities (Galbraith, 1971; Simon, 1973; Tushman and Nadler, 1978). That is, increasing an organization's information processing capability has the effect of making information available to decision makers and, hence, reduces perceived uncertainty. This should lead to better decision making which, in turn, should positively affect organizational effectiveness. For example, if an organization perceives its environment to be rapidly changing, increasing the capability of the organization to process external

information should provide for a better chance of appropriate organizational response since there is less uncertainty in decision making.

2.3.2.1 Organizational Information Processing Requirements

Galbriath's (1971) conceptualization of organizations as information processing systems suggests that the requirement for information and hence information processing is determined by three factors: (1) prior experience in dealing with similar tasks and situations; (2) aspects associated with the organization's size; and (3) the degree of interdependence with other organizational units. Based on the previous discussion, a fourth factor, environmental uncertainty is added to Galbraith's initial formulation.

2.3.2.1.1 Task Uncertainty and Information Requirements

Task uncertainty is defined as the difference between the required information to perform the task and the amount already possessed by the organization (Galbraith, 1977). Task uncertainty is what Perrow (1967) conceptualized as "organizational technology" with the descriptor being the degree to which a task is considered routine or nonroutine.

Galbraith suggests that the amount of information required to perform a task is determined by the goal diversity (e.g., number of

products, markets, clients entering into the decision process),
division of labor (i.e., the number of internal factors about which
information must be processed), and level of goal performance (higher
performance levels require more alternatives and variables to be
considered). Task uncertainty is usually operationalized by
determining the degree of task routinization. That is, routine tasks
(low uncertainty) can be pre planned for and dealt with by employing
rules and standardized procedures. Therefore, the information
processing required is minimized for routine tasks. Non-routine or
complex tasks require "individual attention" since preplanning for all
possible outcomes is either impractical (too many) and/or impossible
(the information doesn't exist to begin with). Hence, more extensive
information processing capacity needs to be designed into those
organizations dealing with non-routine or uncertain tasks (Daft and
Macintosh, 1981). As discussed previously (Section 2.3.1.1), Perrow
identified two dimensions that defined organizational technology:
degree of task analyzability and number of exceptions encountered in
performing the task. Various studies, using several different
instruments to measure Perrow's dimensions of technology, have
indicated convergent validity across the measures of the analyzability
and exceptions dimensions (Withey, Daft and Cooper, 1983). Figure 2.6
adapted from Daft and Macintosh, (1981) summarizes the relationship
between organizational technology and information requirements.

FIGURE 2.6

DAFT AND MACINTOSH (1981) COMPARISON OF PERROW'S (1967)

ORGANIZATION TECHNOLOGY FRAMEWORK AND ORGANIZATIONAL INFORMATION REQUIREMENTS

2.3.2.1.2 Organization Size and Information Requirements

An organization's size is related to several other factors that influence information processing, such as the division of labor (specialization) and number of products. More information will need to be processed if there are many occupational specialties functioning in an organization than if there are few. Similarly for a given size firm, the larger the product line, the more information that must be processed. These factors determine the number of elements relevant for decision making, which, in turn, affects the amount of information to be processed.

This suggests that as an organization gets larger, or increases its product line, or has larger numbers of specialized tasks, information processing requirements increase. However, the tendency in most organizations is to become more formal and bureaucratic (more mechanistic) with increased size (Porter, Lawles and Hackman, 1975; James and Jones, 1976). Unfortunately, increased mechanization precludes increasingly large processing of information since greater formalization, centralization, and specialization does not allow for the processing of unexpected information very well. Hence, as organizations get larger, although there is increased need for information processing, the organization structure typically isn't able to handle the increased information load. In this way, size is a paradoxial element and offers a rationale as to why larger

organizations have become increasingly interested in computer based information systems.

2.3.2.1.3 Degree of Inter-unit Dependence and Information Requirements

The third factor concerns the degree of interrelatedness or interdependence among organizational units. The greater the interdependence among organizational units, the greater the degree of coordination required for concerted action. Thompson (1967) identifies three increasing levels of interdependence (pooled, sequential, and reciprocal) and associates with each an appropriate organizational coordination device (coordination by standardization; plan and mutual feedback; and feedback, respectively). Pooled interdependence happens when each subunit provides a discrete contribution to the whole and each is supported by the whole (for example, a fast food franchise). Sequential interdependence takes a serial form where a direct, ordered interdependence can be specified although the interdependencies need not by symmetrical between subunits (such as in an assembly line). Reciprocal interdependence occurs when the output of each unit becomes the input for the other (such as between marketing and manufacturing departments).

Coordination by standardization involves the establishment of procedures or rules which constrain subunit activity so as to make them consistent with actions taken by others. This strategy requires

situations which are relatively stable, routine and limited to allow matching of situations with appropriate rules. Coordination by plan concerns the establishment of schedules for the interdependent subunits by which their actions can be managed. Coordination by feedback involves the transmission of new information.

March and Simon (1958) state that

> "the more variable and unpredictable the situation,
> the greater the reliance on coordination by feedback."

This implies that an organization needs to have a greater capacity for internal information processing. The important point here is that with increasing degrees of inter-unit dependence more communication (information processing) becomes necessary.

2.3.2.1.4 Environmental Uncertainty and Information Requirements

An organization must somehow acquire and process relevant information from outside its boundaries in order to make appropriate modifications with changes in the environment. In R&D organizations it is especially necessary to stay informed of new technological breakthroughs and developments. A significant amount of research in the area of R&D management has been devoted to identifying the roles that organizational members take in performing this function of information gatekeeping or boundary spanning behavior (Allen, 1966; Pelz and Andrews, 1966; Allen and Cohen, 1969; Smith, 1970; Walsh and

Baker, 1972; Cooney and Allen, 1974; Holland, 1974; Taylor and
Utterback, 1975; Taylor, 1975; Tushman, 1977; Tushman, 1978; Allen,
Lee and Tushman, 1979; Katz and Tushman, 1979; Tushman, 1979; Tushman
and Katz, 1980; Tushman and Scanlan, 1981, Tushman, 1981; Katz and
Tushman, 1981). Although not part of the initial Galbriath
formulation, in the past number of years the impact of the external
environment has been recognized as having implications for the
information processing requirements of the organization (Duncan, 1972;
Child, 1972; Osborn and Hunt, 1974; Downey, Hellriegel, and Slocum,
1975; Huber, O'Connel and Cummings, 1975; Schmidt and Cummings, 1975;
Leifer and Huber, 1977; and Culnan, 1983). As discussed previously,
the state of the environment poses considerable constraints on the
operations and behavior of the organization. Based on environmental
constraints having implications for information processing
requirements, three aspects of the environment are considered
important when ascertaining the environmental contributions to the
information processing requirements of organizational units: (1) the
extent that the environment is considered to be turbulent, uncertain,
and unpredictable, (2) the extent that aspects of the environment are
differentially important to the organizational unit; and (3) the
extent of predictability and control over the environmental elements
(Brown and Schwab, 1983). It is expected that information processing
requirements will be at a maximum if these three elements occur such

that the environment is characterized as being turbulent (changing), complex (diverse), and uncontrollable.

Following Duncan's (1972) typology of environmental uncertainty, Figure 2.7 suggests the information processing requirements for environments ranging from certain to uncertain. The more uncertain the environment, the greater the need for the organization to acquire and process external information in order that accurate states of the environment can be made relevant to that environment (Thompson, 1967).

FIGURE 2.7

COMPARISON OF DUNCAN'S (1972) FRAMEWORK FOR CATEGORIZING ORGANIZATIONAL ENVIRONMENTS AND ORGANIZATIONAL INFORMATION PROCESSING REQUIREMENTS

	COMPLEXITY OF ENVIRONMENT	
	SIMPLE	COMPLEX
STATIC	LOW UNCERTAINTY AND LOW INTERNAL INFORMATION PROCESSING REQUIREMENTS	MODERATELY LOW UNCERTAINTY AND MODERATELY LOW INTERNAL INFORMATION PROCESSING REQUIREMENTS
DYNAMIC	MODERATELY HIGH UNCERTAINTY AND MODERATELY HIGH INTERNAL INFORMATION PROCESSING REQUIREMENTS	HIGH UNCERTAINTY AND HIGH INTERNAL INFORMATION PROCESSING REQUIREMENTS

DEGREE OF ENVIRONMENTAL CHANGE

2.3.2.1.5 Summary of Organizational Information Requirements

Stated in more functional terms, the amount of necessary information to be processed in an organizational unit can be stated in the following form (based on Galbraith, 1973):

$$I = f(U,N,C,E)$$

where

I = the amount of information that must be processed by an organizational unit to insure effective performance.

U = the degree of non-routine technology associated with a unit's task requirements.

N = the number of elements relevant for decision making (itself a function of organization size) such as number of departments, number of occupational specialities, clients, products, etc.

C = the amount of connectedness or interdependence among the elements that are necessary for unit task accomplishment.

E = environmental uncertainty composed of two dimensions: degree of charge and complexity.

The interaction effect between the four contextual variables will determine the organizational information processing requirements.

2.3.2.2 Organizational Information Processing Capabilities

Tushman and Nadler (1978) discuss two aspects of organizational design that affect its information processing capacity: the degree to which the structure is organismic-mechanistic, and the nature of the

coordinating and control mechanisms which integrate the differentiated, but interdependent organizational units.

2.3.2.2.1 Unit Structure

Organic structures have been found to deal with greater amounts of uncertainty than mechanistic forms (Burns and Stalker, 1961 and Duncan, 1973). This implies that different organizational structures will have different information processing capabilities (Tushman and Nadler, 1978). Since organic structures tend to be less formal, decentralized in authority relationships, less impersonal, have less specialized roles, and have greater peer participation in decision making the organizational communication networks tend to be highly connected (Hage, Aiken, Marett, 1971). Highly connected networks, having many paths on which information can flow, tend to be relatively independent on any one indiviual (Delehanty, Sullo, and Wallace, 1982), and, therefore, are able to process more information and are less susceptible to information overload than sparcely connected networks (or mechanistically-oriented structures). Mechanistic organizations are characterized by higher degrees of formality and impersonalization, a centralized authority structure, specialized roles, and less participation in decision making. This organizational structure will tend to constrain offical communication to a more rigid (defined) pattern. A classic example of a mechanistic structure are

military organizations where the "chain of command" clearly defines reporting (communication) relationships.

2.3.2.2.2 Inter-unit Coordinating Mechanisms

The range of coordination and control mechanisms used by organizations suggest that different organizational designs will have different capacities for effective information/data processing. Thompson (1967) suggests appropriate coordination and control mechanisms for each of the three levels of inter-unit dependence discussed earlier (i.e. pooled, sequential and reciprocal). Units making a discrete but basically independent contribution to the organization (pooled dependence) require coordination by standardization. This involves the establishment of procedures or rules which constrain unit activity so as to make them consistent with the actions taken by others. This strategy requires situations which are relatively stable, routine and limited to allow matching of possible situations (future outcomes) with necessary rules or actions. Coordination by plan is necessary for those units operating under a sequential interdependence, coordination and control must be accomplished through a feedback process involving the transmission of information.

The first two mechanisms tend to rely on data processing to provide the means for coordination and control. Recall the

distinction made between information and data, where data was confirmatory in nature. Standardization or plans are effective coordination mechanisms when inputs to or task requirements on a unit confirm an expectation or have programmed responses. When an expectation is not confirmed, that is an exception or something new occurs, these two mechanisms are inappropriate. Galbraith (1973, 1977) proposes a range of coordination and control mechanisms which Tushman and Nadler (1978) rank according to complexity, cost, and information processing capacity. Leifer (1983) adds to this the ability of the coordination and control mechanism to process data (Figure 2.8).

MECHANISM

(1) Rules and Programs

(2) Hierarcy of Authority

(3) Planning and Goal Setting

(4) Formal Information Systems

(5) Lateral Relations

COMPLEXITY	COST	INFORMATION PROCESSING CAPACITY	DATA PROCESSING CAPACITY
Simple	cheap	low	high
↕	↕	↕	↕
Complex	costly	high	low
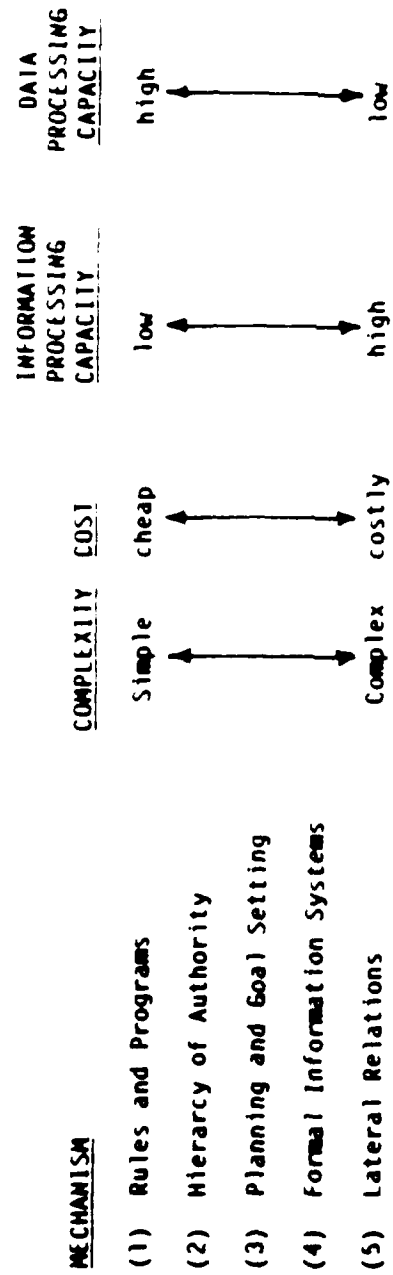
Figure 2.8
Coordination and Control Mechanisms and Information/Data
Processing Capabilities

2.3.2.3 Organizational Effectiveness: Matching Information Processing Capabilities to Requirements

Tushman and Nadler (1978), building on work by Galbraith (1971, 1973), proposed that organizational effectiveness can be expressed as a function of the fit between the uncertainty faced by an organizational unit and the capability of the organizations' design to process required information. An information processing model based on this work is shown in Figure 2.9.

In particular, Tushman and Nadler hypothesized that different organizational designs will have different capacities for information processing and that when organizations are designed to meet their information processing needs problem-solving and decision-making improve. By improving these information-dependent processes, organization effectiveness and performance should be expected to increase.

FIGURE 2.9

TUSHMAN AND NADLER (1978) INFORMATION PROCESSING MODEL
OF ORGANIZATIONAL DESIGN AND EFFECTIVENESS
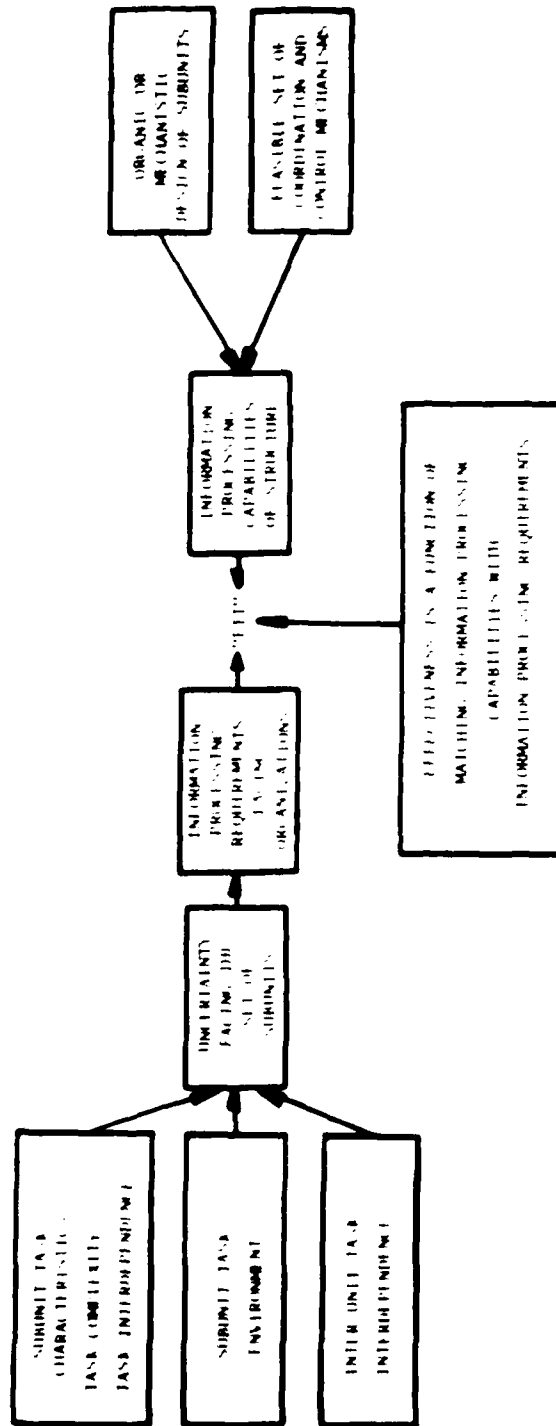
2.4 Summary

This chapter has summarized the rather extensive literature examining the role of communication processes or information flow patterns in R&D organizations. As mentioned, the results of this research have not all been consistent. An identification of the different orientations between research organizations (technology expansion) and development organizations (system/product development) offered a possible explanation for the inconsistent research results. That is, the different orientations of research and development units may lead to different information needs or requirements. If this is true, different organizational designs for research units and development units may be necessary to effectively deal with the varying information requirements. The information processing approach to organizational design and effectiveness provides the conceptual basis for closer examination of this issue. Chapter 3 presents the formalized hypotheses to be examined in this study.

CHAPTER 3

HYPOTHESES

3.1 Introduction

This thesis investigated the relationships specified by Tushman &
Nadler's (1978) information processing model of organizational design
within the context of Air Force Systems Command R&D Organizations. In
addition, this research examined the idea that different
organizational unit designs may be necessary throughout the R&D
process to meet and effectively deal with the changing information
requirements. That is, the organizational designs of R&D units may
need to change as a function of the R&D process in order to maintain a
level of performance (Galbraith, 1973; Zaltman, Duncan, Holbek, 1973).

In particular, this study sought to explore the relationships
among USAF R&D units and the following variables: organizational
technology, environmental uncertainty, inter-unit dependence,
information requirements, organizational structure, inter-unit
coordinating mechanisms, accessibility and quality of information
sources (information processing capability), and organizational unit
effectiveness. The relationships among these variables are shown in
Figure 3.1.

Following is a summary of the research issues to be examined, a
brief discussion of relevant background supporting or leading to the
hypothesis, and a statement of the specific hypotheses. The

FIGURE 3.1

PROPOSED VARIABLE RELATIONSHIPS

TO BE INVESTIGATED BY THIS RESEARCH

R & D PROCESS PHASE	CONTEXTUAL VARIABLES	UNIT I/F REQUIREMENTS	DEGREE OF FIT	UNIT I/F CAPABILITY	ORGANIZATION DESIGN VARIABLES
TECHNOLOGY DEVELOPMENT	TECHNOLOGY	INTRA UNIT		INTRA UNIT	STRUCTURE
SYSTEM DEVELOPMENT	ENVIRONMENT	INTRA ORG.		INTRA ORG.	COORDINATING MECHANISMS
	DEPENDENCY	EXTRA ORG.		EXTRA ORG.	

EFFECTIVENESS PERFORMANCE
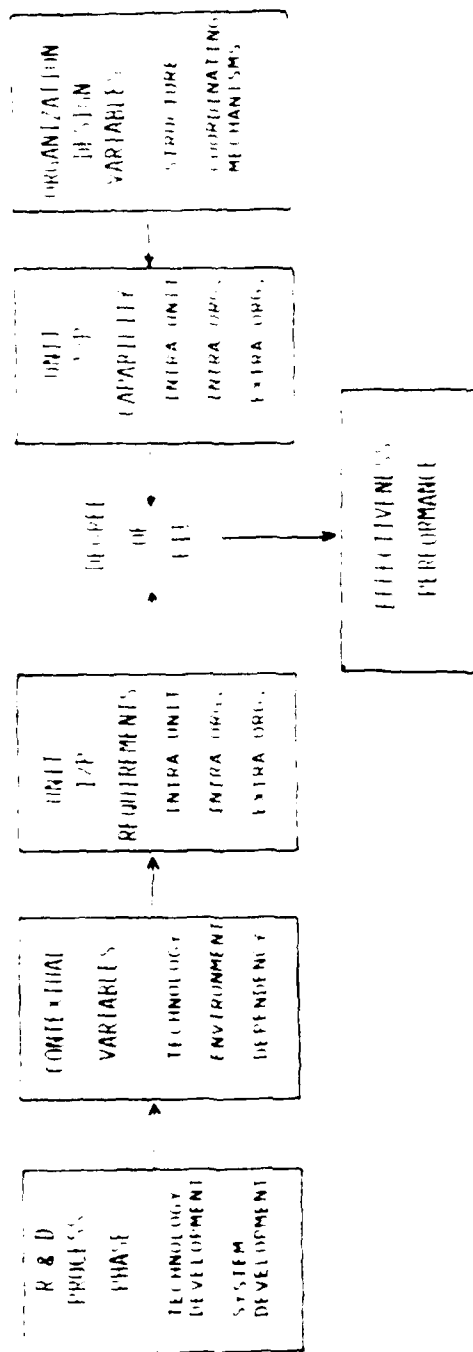
literature related to each of these hypotheses is discussed at greater length in the previous chapter.

3.2 Research and Development Influences on Contextual Variables

The first research issue examined was whether perceptions of the contextual variables of organizational technology, environmental uncertainty, and inter-unit dependence differ according to the phase of the R&D process.

3.2.1 Hypothesis 1: Effect of Research versus Development on the Perception of Non-Routine Technology

Research and development activities can be thought of as an uncertainty reduction process, with each phase of the process acting to reduce the technical uncertainty of a developing technology or system (Archibald, 1976). Holtz (1969) suggests that in the early phases of R&D, the tasks are theoretically-oriented and widely varied, while in the later phases the activities are more structured and less varied. Thus, the following hypotheses are proposed using Perrow's (1966) concept of organizational technology.

Hypothesis 1a: The perceived number of task exceptions will be greater for research units than for development units.

Hypothesis 1b: The degree to which tasks are perceived as unanalyzable will be greater for research units than for development units.

Hypothesis 1c: The perception of non-routine technology will be greater for research units than for development units.

3.2.2 Hypothesis 2: Effect of Research Versus Development on the Perception of Environmental Uncertainty

Although the degree of non-routine technology is expected to decrease as progress is made through the R&D process, the degree of perceived environmental uncertainty, composed of those factors outside the organizational unit that affect its work, is expected to be greater in units in the later phases of development. As work progresses from technology to systems development, that is as the project gets closer to being an operational reality, special interest groups, internal and external to the R&D organization, become more involved in the work being done within a project unit. For example, the "Using" Air Force Command (customer) gets more concerned with how the new system will perform, the Supporting Command (Air Force Logistics Command AFLC) becomes more involved in how the system will be maintained, and the Testing organizations get involved in evaluating the system. In addition, as the system nears production approval, typically where large amounts of funds are required, higher levels of management, both within and outside the R&D organization, become interested. All of these factors existing outside of the organization can exert influence the work being performed in the R&D project unit; the Using Command may change the performance or schedule requirements, the Supporting Command may require certain reliability or maintainability, and higher management may modify R&D project funding.

Based on the dimensions of environmental uncertainty discussed in Chapter 2, the following hypotheses are proposed:

Hypothesis 2a: Development units will perceive the environment as more complex than will research units.

Hypothesis 2b: Development units will perceive the environment as more dynamic than will research units.

Hypothesis 2c: Development units will perceive the environment as less predictable than will research units.

Hypothesis 2d: Development units will perceive the environment as less controllable than will research units.

Hypothesis 2e: Development units will perceive the environment as more uncertain than will research units.

3.2.3 Effect of Research versus Development on the Perception of Degree of Perceived Inter-unit Dependence

The third contextual variable to be considered in this research is inter unit dependence, which involves the extent to which units are interrelated in performing their work processes. Thompson (1967) conceptualized three levels of interdependence (pooled, sequential and reciprocal) among organizational units. Pooled dependence is the case where each unit within the organization makes a discrete contribution relatively independent from other units. In this case, each unit has little dependence on the other organizational units in performing its

work. Reciprocal dependence represents the other extreme in that the outputs of each unit become the inputs for the other. In this case, units rely heavily on each other in order to get their work done to achieve organizational objectives. In the technology development area, where activities are concerned with expanding the state of scientific knowledge in a specific area, unit members work relatively independent from other units in the organization. This is not to say that unit members working on technology development projects should not interact with others in the organization (they might find a creative insight to a similar problem solved by someone from another unit), but by the nature of their work they are the "resident experts" in the technology area. In this sense, they are not <u>required</u> to interact to a great extent with other units, with the exception of possibly having to negotiate for common resources. In the system development phases, activities often require the coordination, and often approval, of other functional units within the organization, such as with manufacturing and marketing. As such, it is anticipated that a high degree of inter-unit dependence will be evident in the system development phases.

Thompson's framework of inter-unit dependence suggests that there are two dimensions of interdependence between organizational units: the degree that a unit is dependent on other organizational units to accomplish its work goals, and the extent other organizational units

are dependent on the unit to accomplish their work goals. Based on
these dimensions, the following hypotheses are proposed:

Hypothesis 3a: Development units will perceive a greater degree of
dependence on other organizational units than will research units.

Hypothesis 3b: Development units will perceive to a greater extent
than other organizational units are dependent on them than will
research units.

Hypothesis 3c: Development units will perceive a greater extent of
inter-unit dependence than will research units.

3.3 Contextual Variables and Unit Information Requirements

The second set of hypotheses concern the relationship among the
contextual factors of organizational technology, environmental
uncertainty and inter-unit dependence, and the organizational unit's
information processing or communications requirements. The
information processing activities of a unit can be differentiated into
the following four categories: with the unit supervisor/manager,
among unit members, intra-organizational (outside the unit but within
the organization) and extra-organizational (outside the
organization). These hypotheses propose that the contextual variables
will influence a unit's information processing requirements in
predictable ways.

3.3.1 Hypothesis 4: Relationship between Unit Technology and Information Processing Source Requirements

Task uncertainty or organizational technology is usually operationalized by determining the degree of task routinization (Withey, Daft and Cooper, 1982). That is, routine tasks (low uncertainty) can be preplanned for, and dealt with, by employing rules and standardized procedures. Therefore, required information processing is minimized for routine tasks. Non-routine tasks typically require "individual attention" since preplanning for all possible outcomes is either impractical (too many) or impossible (the information does not exist). That is, individuals are often confronted with novel and unexpected events or situations. Hence, more information processing will be required in dealing with non-routine or uncertain tasks. Most studies have generally supported the notion that task uncertainty is associated with greater information processing (Tushman, 1978, 1979, Daft and Macintosh, 1981). Using Perrow's (1966) dimensions of organizational technology, the following hypotheses are proposed.

Hypothesis 4a: The number of task exceptions will be positively related to information source requirements.

Hypothesis 4b: The degree of task analyzability will be negatively related to information source requirements.

Hypothesis 4c: Non-routine technology will be postively related to information source requirements.

3.3.2 Hypothesis 5: Relationship Between Environmental Uncertainty and Information Processing Source Requirements

A number of studies have identified a general relationship between perceived environmental uncertainty and the need for external information processing, including: Duncan, 1972; Child, 1972; Osborn and Hunt, 1974; Hellriegel and Solcum, 1975; Huber, O'Connel and Cummings, 1975; Schmidt and Cummings; Leifer and Huber, 1977; Leifer and Delbecq, 1978; and Culnan, 1983. In the area of R&D management, a great deal of research has been devoted to identifying and describing the technological gatekeeping or boundary spanning behavior of individuals responsible for extra-organizational information processing. However, this research has been inconclusive in that some studies did not indicate that the gatekeeping function was occurring in some R&D units. (Johnston and Gibbons, 1975; Pruthi and Nagpaul, 1978). This result may be attributable to different research methdologies; however, a more promising explanation is that the R&D groups studied were not comparable. That is, the environmental conditions may have been different, resulting in more or less of a need to process external information. The more uncertain the environment, the greater the need for the organization to acquire and process external information in order that the state of the environment be monitored and assessed so that accurate decisions can be made relevant to that environment (Thompson, 1967). For the

dimensions of environmental uncertainty presented in Hypothesis 2,
information requirements for environments ranging from certain to
uncertain can be hypothesized.

Hypothesis 5a: Complexity of the environment will be postively
related to extra-organizational information source requirements.

Hypothesis 5b: Dynamism of the environment will be positively
related to extra-organizational information source requirements.

Hypothesis 5c: Unpredictability of the environment will be
positively related to extra-organizational information source
requirements.

Hypothesis 5d: Uncontrollability of the environment will be
postively related to extra-organizational information source
requirements.

Hypothesis 5e: Environmental Uncertainty will be postively related
to extra-organizational information source requirements.

3.3.3 Hypothesis 6: Relationship Between Inter-unit Dependence and Inter-Unit Information Source Requirements

The greater the degree of interdependence among organizational
units, the greater the degree of coordination required for concerted
action. With each of Thompson's (1967) three increasing levels of
inter-unit dependence (pooled, sequential and reciprocal), he associates
an appropriate organizational coordination device (coordination by
standardization plan and mutual feedback and feedback, respectively).
Coordination by standardization involves the establishment of procedures
or rules which constrain unit activities so as to make them consistent

with the action taken by others. Coordination by plan concerns the establishment of schedules for interdependent units by which their actions can be managed. Coordination by feedback involves the transmission of new information. March and Simon (1958) suggest that the more units are dependent upon one another, the more variable and unpredictable the situation, and the greater the reliance on coordination by feedback (information processing). The important point here is that with increasing degrees of inter-unit dependence, more communication (information processing) becomes necessary, hence the following hypotheses are proposed.

Hypothesis 6a: Dependence on other organizational units will be positively related to inter-unit information source requirements.

Hypothesis 6b: Other organizational units' dependence on a unit will be positively related to that unit's inter-unit information source requirements.

Hypothesis 6c: Inter-unit dependence will be positively related to inter-unit information source requirements.

3.4 Organizational Design and the Accessibility and Quality of Information Sources

Different organizational designs have been developed with distinct characteristics and different efficiencies for processing information (Leifer, 1979). Hall and Ritchie (1975) concluded that organizational design was the main factor influencing the flow of information in an R&D

unit. Two factors have been shown empirically to influence an individual's selection and use of an information source or channel: the accessibility to, and the quality of information sources (Gerstberger & Allen, 1969; Rogers & Shoemaker, 1971; and O"Reilly, 1983). As factors influencing information flow, accessibility and quality can be viewed as surrogates of the information processing capability associated with a source. The effect of organizational design differences on the accessibility and quality of information sources are explored in the following hypotheses.

3.4.1 Hypothesis 7: Relationship Between Unit Structure and the Accessibility and Quality of Information Sources

Burns and Stalker (1961) use the terms mechanistic versus organic to describe the endpoints on an organizational structure continuum. The mechanistic organization is characterized by high formalization of rules and procedures, strict adherence to the chain-of-command, communication that is primarily directed downward, and infrequent task feedback. An organic structure is characterized by low formalization of rules and procedures, a lack of adherence to the chain of command, open communication channels, and frequent task feedback. In this way, an organic unit structure tends to have a more flexible and adaptable organizational boundary than a mechanistic structure in the sense that it places fewer constraints on its members communication behavior.

With a more permeable boundary, it is expected that an organic
structure would allow external information to be more readily
processed since more unit members are permitted to be "linked" (have
contacts) to the external environment. Considering the dimensions of
structure discussed in Chapter 2, the following hypotheses are
proposed.

Hypothesis 7a: The extent of centralization in a unit structure will
be negatively related to the accessibility and quality of information
sources.

Hypothesis 7b: The extent of formalization in a unit structure will
be negatively related to the accessibility and quality of information
sources.

Hypothesis 7c: The extent of specialization (division of labor) in a
unit structure will be negatively related to the accessibility and
quality of information sources.

Hypothesis 7d: The more mechanistic a unit structure is, the less
the accessibility and quality of information sources.

3.4.2 Hypothesis 8: Relationship Between Inter-Unit Coordinating
Mechanisms and the Accessibility and Quality of Information
Sources

Galbraith (1973) suggests a range of coordinating mechanisms,
based in part on Thompson's (1967) work, that organizations adopt for
integrating and controlling the activities of their units. Tushman
and Nadler (1978) rank these mechanisms according to their ability to

process information (Reference Figure 2-8). The following hypothesis results from this work.

Hypothesis 8: The extent of inter-unit coordination will be positively related to the accessibility and quality of inter-unit information sources.

3.5 Hypothesis 9: Unit Effectiveness as a Function of the Difference Between Information Source Requirements and the Accessibility and Quality of Information Sources.

Problem-solving and decision-making, by individuals or groups, cannot be made without adequate information and hence, the effectiveness of these activities are dependent upon the ability to obtain and process information. The extent to which an organizational unit must search for and process information is related to the extent to which there is uncertainty on the part of unit members. The greater the perceived level of uncertainty, the greater the need for information to reduce the uncertainty to comprehensible levels. The level of uncertainty facing a unit, and thus it's information processing requirements, result from perceptions by unit members of certain contextual factors. In terms of this research, a unit's information processing requirements originate from uncertainties (1) within the unit (extent of non-routine technology), (2) among units within the organization (extent of inter-unit dependencies), and (3) between the unit and outside forces (environmental uncertainty). Organizational design is proposed as a method for dealing with the

different information processing requirements. Tushman and Nadler (1978, 1980) propose that effectiveness is a function of matching a unit's information processing capabilities, through organizational design, to its information processing requirements. Hence, the following hypothesis is proposed.

Hypothesis 9: Effectiveness will be positively related to a unit's matching information source requirements to the accessibility and quality of information sources.

Figure 3.2 serves as a summary of the literature reviewed pertaining to development of the information processing approach to organizational design, as well as a framework for illustrating the hypotheses investigated by this research.
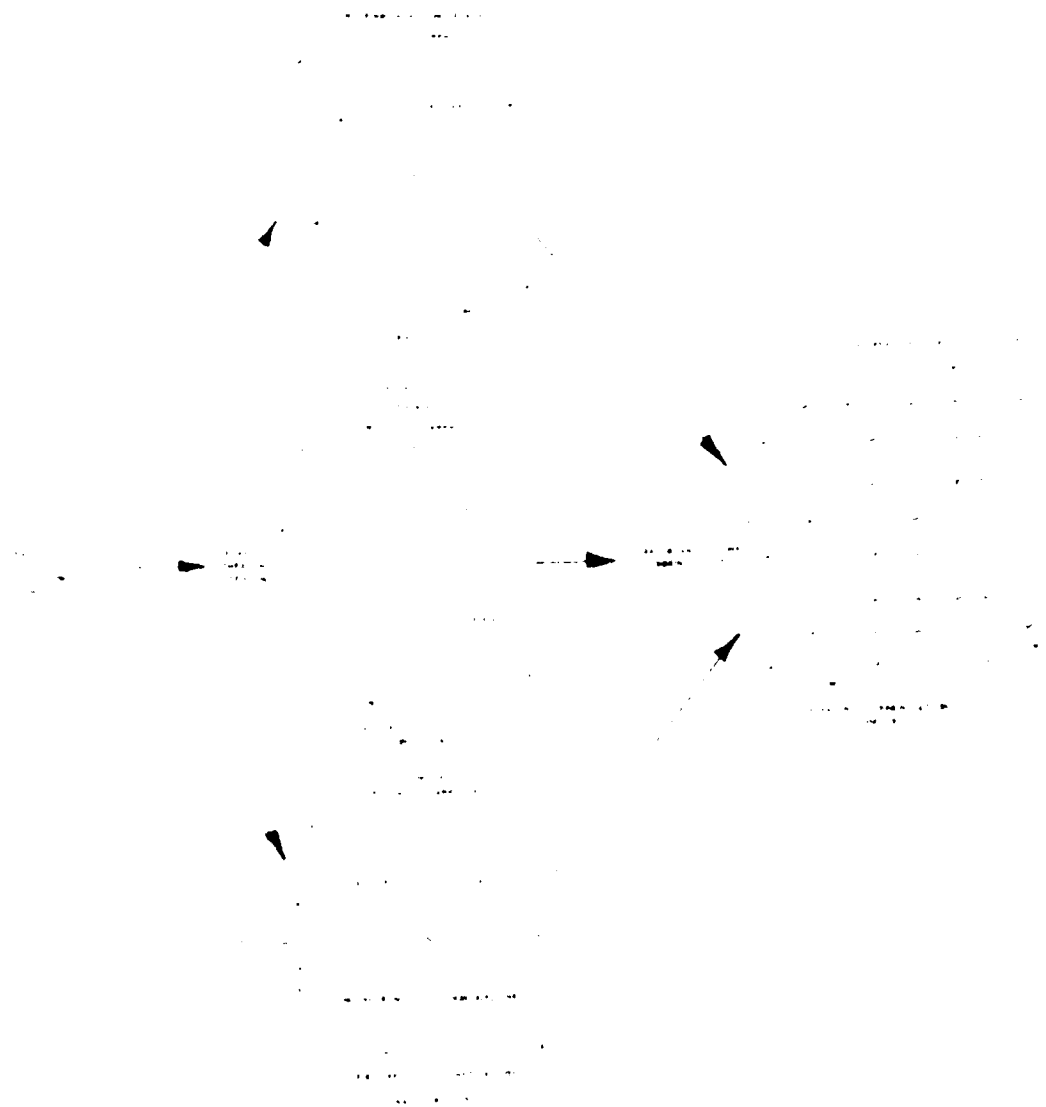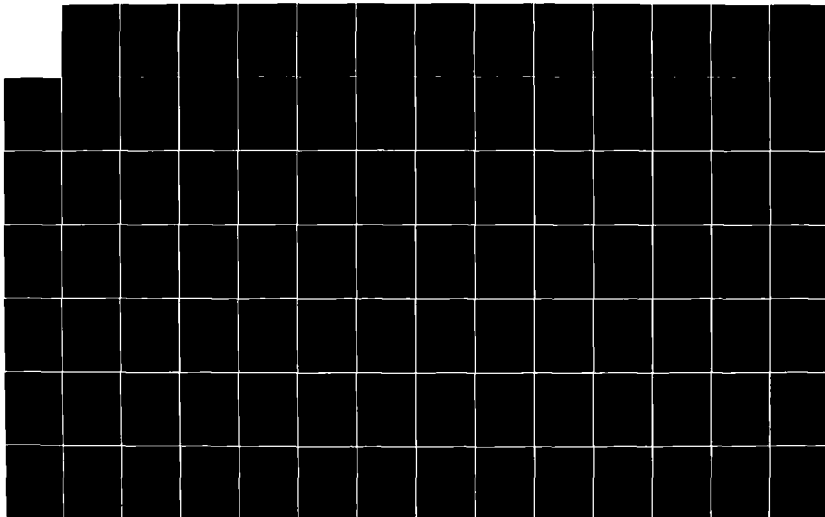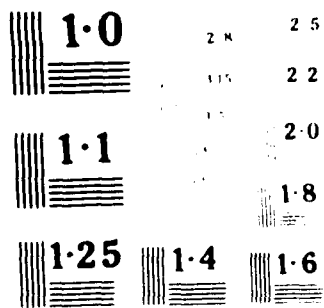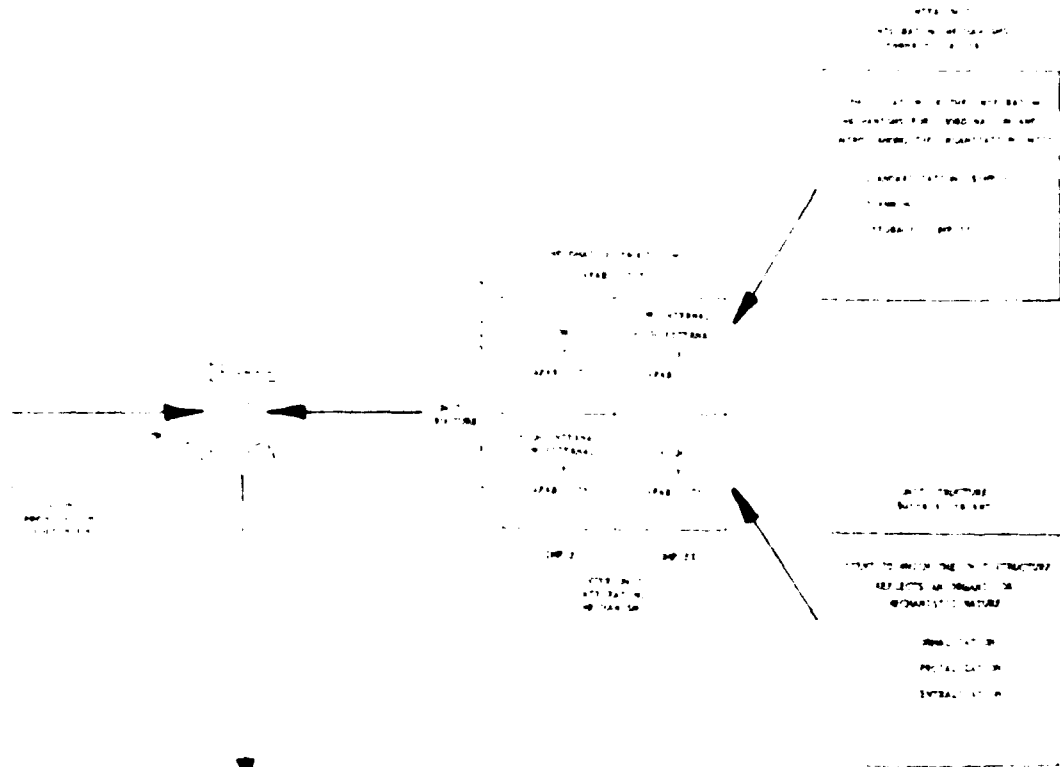
CHAPTER 4

METHODOLOGY

4.1 Introduction

This research study investigates the information processing model
of organizational design within a field setting. Thus, the research
design for this study can be considered as passive observational or as
a natural occurring experiment, which Cook and Campbell (1979) suggest
are appropriate for causal inference. In addition, the thrust of the
research is macro oriented in that it builts on and integrates the
results of previous empirical research in the areas of contingency
theory, organizational design, information processing, and
effectiveness. A significant amount of research has been conducted
which examines components of the information processing model;
however, there have been few studies that operationalize and
investigate the relationships within the overall model as
conceptualized by Tushman and Nadler (1978). The information
processing approach provides a potentially powerful conceptual
backdrop from which both organizational design and computer-based
information systems design can be viewed. However, field research on
the Tushman/Nadler conceptual model is necessary before empirically
sound recommendations can be made for management's consideration.

This thesis attempts to provide additional insight into the workings of the information processing model through its empirical orientation.

A field context is necessary since a primary purpose in performing this research is to provide for descriptive relevance and operational validity to the organizations involved. Thomas and Tymon (1982) define descriptive relevance as the accuracy of research findings in capturing phenomena encountered by the practitioner in his or her organizational setting. Operational validity concerns the ability of the practitioner to implement action implications of a theory by manipulating causal or independent variables. Since this research is supported by the subject population, both descriptive relevance and operational validity are desirable attributes to maximize.

4.2 Data Collection Instruments

This section discusses the two instruments developed to collect data on the information processing model dimensions identified in Figure 4.1. A survey was developed to collect data from R&D work group or unit members on their perceptions of contextual variables (organizational technology, environmental uncertainty, and inter-unit dependence), organizational variables (unit structure and inter-unit coordination) information needs, and the accessibility to and quality

FIGURE 3.1

AN OPERATIONALIZATION OF THE INFORMATION PROCESSING MODEL
OF ORGANIZATIONAL DESIGN AND EFFECTIVENESS

of information sources. A second survey was developed to provide effectiveness measures on each on the work units surveyed. Each variable will be subject to a confirmatory factor analysis, the results of which are reported in section 4.6.

4.2.1 Unit Member Survey

Sections of the unit member survey measure different variables. All items within the unit member survey use 7-point, Likert-like scales. The survey items are largely a combination of other instruments used in previously conducted research, although some items have been tailored to the R&D setting. Table 4.1 identifies the sources of the various scales used within the survey. Appendix A contains the complete questionnaire and related documents.

4.2.1.1 Organizational Technology

The purpose of this section of the survey (10 items) was to provide a measure of the degree to which the unit tasks involve non-routine technology. Perrow (1967) proposed two dimensions of technology for the comparative analysis of organizations: number of exceptions and degree of task analyzability. Exceptions refer to task variety, meaning the extent to which unexpected events occur in the

TABLE 4 1

SOURCES OF VARIABLE SCALES USED IN STUDY

Major Variable	Operationalization	Scale/Dimension	# Items	Source
Technology	Routine Nonroutine	Exceptions Analyzability	5 5	Withey, Datt, & Cooper (1983)
Environmental Uncertainty	Certain Uncertain	Change Complexity Control Predictability	4 4 2 4	Based on work by Duncan (1972)
Inter Unit Dependence	Degree of Interdependence	Dependent on Others Others Dependent	4 4	Based on work by Thompson (1967)
Unit Structure	Organic Mechanistic	Formalization Specialization Centralization Impersonality	4 4 5 2	Leiter & Huber (1977)
Integrating Mechanism	Inter Unit Coordination	Extent of Coor	6	Based on work by Thompson (1967) & Galbraith (1973)
I/P Requirement	Information Source Requirement	Need	2	Based on work by Roberts & O'Reilly
I/P Capability	Information Source Accessibility and Quality	Accessibility of Source Quality of Source	3 5	Based on work by Roberts & O'Reilly
Effectiveness	Effectiveness	Productivity Adaptability Cooperation Anticipation of Problems Cost Schedule Technical	3 2 1 1 1 1	Based on work by Mott (1972) and Brabson (1982)

process of converting inputs into outputs. Analyzability refers to
the extent to which the task can be performed using an objective,
computational procedure versus an intuitive or search intensive
problem solving mode. Typically, these dimensions are combined to
form a unidemensional continuum representing the degree to which the
technology is routine or non routine. Several scales have been
developed over the years operationalizing Perrow's concept of
organizational technology. More recently, a scale developed by
Withey, Daft, and Cooper (1983), combining the features of several
other scales (Van de Ven & Delbecq,1974; Van de Ven & Ferry, 1980;
Sims, Szilagyi & Keller, 1976; and, Daft & Macintosh), indicates a
high degree of face and convergent validity. Each dimension is
measured from five items. The unweighted average of the two
dimensions provided a score for each individual, used as a measure of
the perceived degree of non routine technology. The scores of the
unit members were then averaged and the resulting value used as a
measure of the non routine technology associated with a particular
unit. Withey, Daft and Cooper report Cronbach alphas for the
exception and analyzability dimension scales of .81 and .85,
respectively.

4.2.1.2 Environmental Uncertainty

Environmental uncertainty (PEU) stems from factors and forces outside the unit that influence or effect the work being performed by the unit. These demands and pressures may come from individuals, groups or other organizations. Environmental uncertainty is segmented in terms of originating from factors either (1) inside the organization to which the unit belongs (i.e., a laboratory or product division) or, (2) from outside the organization. The scale is based on research by Duncan (1972), Leifer & Huber (1977) and Brown & Schwab (1983). Each of the two sources of perceived environmental uncertainty are measured from the sum of seven items addressing the following dimensions of: change, complexity, predictability and controllability. Hence, the measure of a unit's extra organizational environmental uncertainty will be obtained by the differentiation between a unit member's perceptions of organizational environmental uncertainty and extra organizational environmental uncertainty.

4.2.1.3 Inter-Unit Dependence

Inter unit dependence is a measure of the degree of dependency between a unit and other units in the organization in terms of accomplishing work related tasks. Four items are used to assess the

degree that a unit is dependent upon other organizational units in order to perform its work. Similarly, four items are used to assess the degree that other units are perceived to be dependent upon the surveyed unit in order to perform their (the other unit's) work. This strategy for measuring inter unit dependence is based upon Thompson's (1967) framework concerning the relative dependency relationships among organizational units. The individual items were selected on recommendations by experienced individuals in the field of R&D Management. The items were summed and averaged over unit members to give an overall assessment of inter unit dependence.

4.2.1.4 Unit Structure

The unit structure section of the questionnaire was developed from Leifer and Huber (1977) and Kmetz (1981), which assesses the extent to which a structure can be considered organic or mechanistic (Burns and Stalker, 1966). Four dimensions of structure were addressed: formalization (eight items), centralization (five items), specialization (eight items), and impersonality (two items). Formalization is concerned with the degree to which rules, procedures and instructions are written (made explicit). Centralization, or hierarchy of authority, involves the location of authority within the

unit to make legitimate decisions. That is, whether decision making authority is vested in one position or whether it is decentralized in the unit. Pugh, Hickson, Hinings and Turner (1969) define specialization as the division of labor within the organization; the distribution of official duties among a number of positions. Impersonality is the extent to which interpersonal interactions formal or constrained by the unit. A mechanistic structu is characterized as having high degrees of formalization, centralizacion, impersonality and specialization (narrow division of labor). By summing the unweighted mean scores for each of the four dimensions, and average score for each member's perception of unit structure is obtained.[3] The average scores for each individual in the unit were used as the organic/mechanistic score for that unit.

4.2.1.5 Inter-Unit Coordination

Lawrence and Lorsch (1967) state that organizations become differentiated in order to better deal with specific aspects of their environments. However, the greater the differentiation or

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[3]Leifer (1976) found that the mean values of the dimensions of unit structure load on one factor, providing a rationale to the organic-mechanistic continum.

segmentation of the organization, the greater the need for an integration mechanism that will provide for coordination and control among the units. Galbraith (1973) proposes a range of coordination and control devices, based in part on work by Thompson (1967), that an organization may use to coordinate the activities of its work units. Based on this conceptual work, a set of five items was composed to assess the extent of inter unit coordination. The sum of these five items, averaged over unit members, provided a measure of the perceived extent of inter unit integration or coordination between this unit and others in the organization.

4.2.1.6 Information Source Requirements

A unit's information requirements will be examined from work unit member's communications with four mutually exclusive sources or channels: (1) immediate superior, (2) other unit members, (3) others outside the unit, but within the organization, and (4) others outside the organization. Individual information processing requirements will be assessed from two items. One item concerns the perceived importance of each information source. The second item asks a respondent to identify which source(s) is likely to have information that he would find useful in doing their job. The sum of these two

items, averaged over unit members, was used to provide a measure of the unit's overall information processing requirements.

4.2.1.1 Accessibility/Quality of Information Source

Two factors have been shown empirically to influence an individual's selection and use of an information source or channel: the accessibility to and the quality of information sources (Gerstberger & Allen, 1969; Rogers & Shoemaker, 1971; and, O'Reilly, 1983). These factors can be viewed as predictors of the extent to which a channel or source of information is capable of providing information. If a source of information is characterized as highly accessible, it has high information processing potential or capability. Conversely, if an information channel is characterized by low accessibility, and has information of dubious quality, the potential for information processing is reduced. Figure 4.2 presents a framework for viewing the influence of quality and accessibility on information processing capability. Three items in the questionnaire were used to measure information accessibility, while five items are used to assess information quality. These items were adapted from research by O'Reilly (1983). Information accessibility for each of the four sources of information are: availability of information from

a source the ease to get at an information source and the difficulty in getting information from a source. The average of the three items for each source provided a measurement of accessibility for that source An average over the unit provided a measure of the perceived accessibility for each source. The five items used to assess information quality were: accuracy, specificity, relevance, reliability, and quality. Measures of information quality were calculated in a procedure similar to the one used in the calculation of information accessibility.

FIGURE 1.

ACCESSIBILITY AND QUALITY OF INFORMATION AS A SUBSTRATE
OF INFORMATION PROCESSING CAPABILITY

LOW I.P. CAPABILITY	PROCESSING INTERFERENCE DUE TO INFORMATION OVERLOAD
INABILITY TO OBTAIN INFORMATION LEADS TO INFORMATION UNDERLOAD	HIGH I.P. CAPABILITY

LOW   HIGH

ACCESSIBILITY OF INFORMATION

QUALITY
OF
INFORMATION
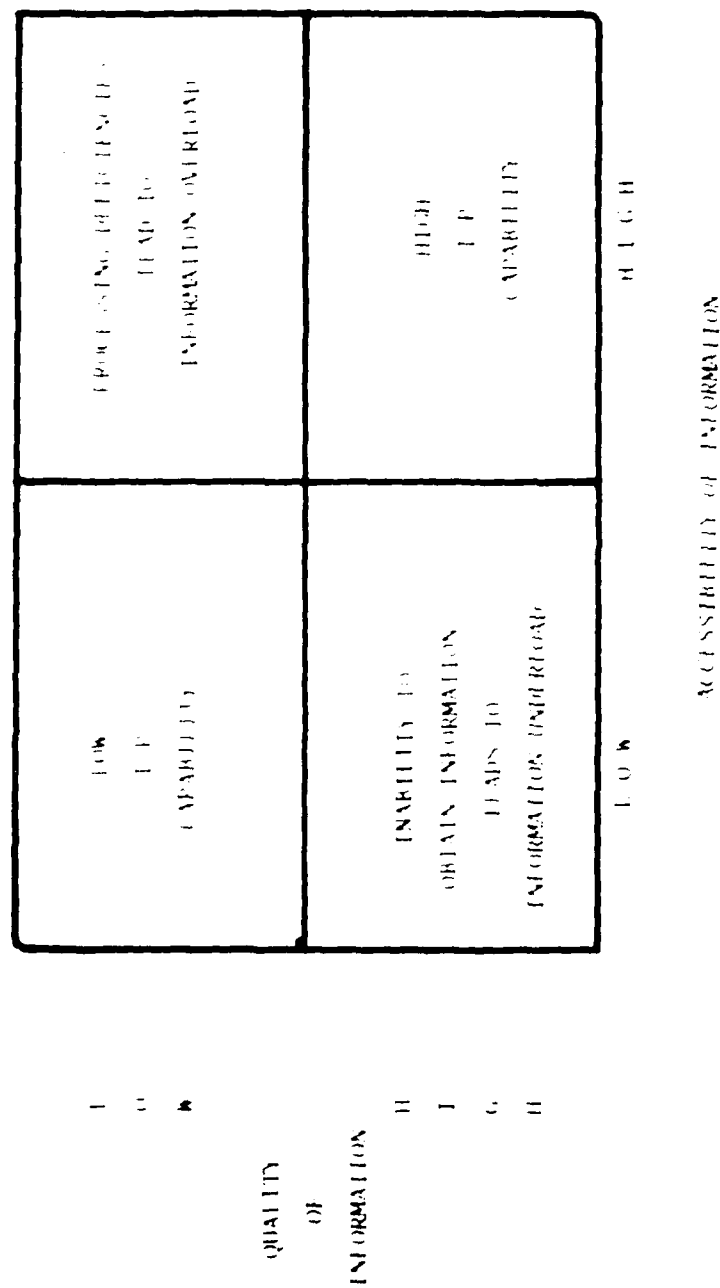
4.2.2 Evaluator Survey

Performance measures have been typically difficult to develop for R&D (Whitley & Frost, 1971). An extensive study by the Hughes Corporation (1974) into the factors effecting R&D Productivity concluded that both quantitative and qualitative performance measures are necessary. The questionnaire developed for this thesis was based, in part, on research done by the Hughes Corporation (1974) and Brabson (1982). Brabson designed a questionnaire specifically for the evaluation of USAF Laboratories. Hence, the questionnaire is considered an appropriate instrument for this study. The "qualitative " effectiveness measures used were previously validated and reported by Mott (1972) in a study of several federal government organizations. Four measures are derived from Mott's seven items in the set: (a) overall effectiveness, the sum of seven items, (b) productivity, the sum of three items, (c) adaptability, the sum of two items, and (d) anticipation of future problems, one item (qualitative measures). In addition, the general R&D program management parameters of technical cost, and schedule performance ("quantitative measures") were assessed by one item each. Appendix B contains the Evaluator Survey.

The evaluator's survey was administered to division or section
chiefs within the organization to provide an assessment of the
effectiveness and performance of the units. A procedure similar to
that used by Tushman and Katz (1980) was employed. Each manager was
administered a survey and asked to independently evaluate the overall
performance and effectiveness of the units with which he or she was
familiar. If the manager could not make an informed judgement for a
particular unit, he or she was be asked not to rate the unit. Each
unit was independently rated by two or three managers on a nine-point
scale. The ratings of managers were rank correlated to determine if
averages of the individual ratings could be used to yield overall unit
performance scores.

4.2.3 Instrument Validity

Face and content validity of the measures used in the
questionnaires were demonstrated by a review of the literature and
through the subjective evaluation of experts in the field. Face
validity of the scales were improved through use of a field pilot
study. The technology, environmental uncertainty, structure,
information processing capability and performance scales were all
generated from well documented and established instruments in the

field of organizational research. Their validity is generally accepted in the literature. All the measures within a unit were assessed for convergent validity in the data collected for this research.

4.3 Pre test Analysis

A pre test of the general research approach and data collection instrument was conducted at a Military R&D Facility. The purpose of the pre test or "pilot study" was to simulate and assess the general research methodology within a field setting, one that closely parallels the field sites eventually used in the thesis research. Specifically, the results from the pre test were intended to provide initial reliability measures on the data collection instrument, and provide feedback on the feasibility of the research approach (e.g. the length of and the time required to complete the survey). The organization used for the pilot study was consistent with the technology expansion (Research) and systems development (Development) subprocesses discussed in Chapter 2.

Five units were approved for participation in the pilot study by senior management. Three units were concerned with research efforts and two units were included in development activities. A total of

twenty three questionnaires were distributed to the individuals within these units; twenty one were returned (91% response), with twenty being usable (87%). Several implications concerning the proposed research methodology resulted from the pilot study and its analysis, including:

1. Revisions were made to several of the scales based on the pilot study reliability analysis.

2. A shorter version of the survey was developed for data collection in the field sites in order to improve response rate.

3. The pilot study reinforced the idea that on site data collection was necessary to get the desired response rate.

4. The pilot study provided an opportunity for investigator "training" in data collection procedures.

5. The analysis used for the pilot study was a valuable experience in terms of developing a data input and analysis methodology.

4.4 Field Sites and Subjects

The field setting selected for this research consisted of organizations within the Air Force Systems Command (AFSC), which is responsible for all USAF research and development activities. AFSC is organized into four major areas: Laboratories, Product Divisions, Test Ranges & Centers, and Specialized Divisions. The twelve laboratories and four Product Divisions are organizations within AFSC

responsible for most of the research and development activities within the USAF.

The activities of the research laboratories are directed toward "technology expansion", while the Product Divisions are oriented toward "system development" type of activities. The specific organizations and sites chosen in this study are shown in Table 4.2.

The Rome Air Development Center (RADC) and the Electronic Systems Division (ESD) are organizational components of AFSC that are responsible for the research and development of electronic systems/subsystems (such as ground based radar and military

Table 4.2

Identification and Location of Field Sites

Organization	Site
Laboratories	
Rome Air Development Center	Griffiss AFB, NY
Aero Propulsion Laboratory	Wright-Patterson AFB, OH
Avionics Laboratory	Wright Patterson AFB, OH
Flight Dynamics Laboratory	Wright Patterson AFB, OH
Product Divisions	
Electronic Systems Divison	Hanscom AFB, MA
Aeronautical Systems Division	Wright Patterson AFB, OH

communication systems). The Aero Propulsion, Avionics and Flight Dynamics laboratories are three of the four Air Force Wright Aeronautical Laboratories (AFWAL) which are responsible for performing research on aircraft systems and subsystems. The Aeronautical Systems Division (ASD) is primarily responsible for activities leading to the development of new aircraft or aircraft systems.

Data was collected from eighty work groups, or units, within the four laboratories and two Product Divisions. Each work group was formally recognized by the organization. That is, a formal management or supervisor position existed within each work unit. Furthermore, work units were selected at the lowest formally recognized level in the AFSC organizations to maintain inter organizational comparability.

Forty two research (laboratory) and thirty eight development (Product Division) work units, randomly selected, provided data for this study. Of 861 surveys distributed, 561 usable responses were returned (65.2% response rate). This response rate is actually a lower bound since individuals within the R&D units report they travel 10 15% of the time. These sites, although part of a larger organization (Air Force Systems Command), are relatively homogeneous, and can be differentiated by the major missions of their

organizations, namely a research versus a development orientation.[4]

Average individual response rates categorized by Research and by Development are presented below:

Table 4.3

Survey Response Rates for Research and Development Personnel

	Individuals surveyed	Usable # Returned	Response Rate
Research	520	342	65.7%
Development	341	219	64.2%
Total	861	561	65.1%

[4] Multiple comparison tests were performed between the organizations which confirmed that two groups (Research and Development) were a valid categorization of the organizations.

The average work group, or work unit, size was 11.1 professional (technical) personnel with a mean unit member response rate of 65.0%. Table 4.4 identifies the number of units surveyed, mean work unit size, and mean unit response rate for research and for development. The lower response rate for development units is attributed to the greater travel rate reported by those personnel (p. < .05).

The sample population returning usable surveys was considered representative of the overall population based on a comparison of demographic statistics. Demographic data obtained from unit members did not indicate a significant difference between the formal positions within the units (Table 4.5). The position titles within a unit size of eleven would be a manager or supervisor of the technical group, three or four group leaders or senior engineers/scientists, six or seven engineers/scientists, and an occasional technician. A significant difference was found in the extent of formal education, members of research units reported a greater number of advanced degrees (Table 4.6). Table 4.7 indicates that nearly 75% of the sample reported a degree in one of four technical disciplines: Electrical Engineering (34%), Aeronautical Engineering (15%), Mechanical Engineering (11%) and Physics (13%). Management degrees accounted for 13% of the sample.

Individuals involved in research had, on average, a greater number of degrees in the Sciences than did development personnel (30% vs. 20%), while development had a higher percentage of personnel with management degrees (21% vs 9%). The percentage of individuals with Engineering degrees was 64% for development and 61% for research (see Table 4.8).

Table 4.4
Summary of R&D Organizational Units Surveyed

	Mean Unit # Surveyed	Mean Unit Size	Response Rate
Research Units	42	13.0	72.1%
Development Units	38	9.0	63.9%

Table 4.5

Demographic Statistics Position in Work Unit

	Research	Development	Total	Percent
Unit Manager	37	30	67	12%
Group Leader/Senior Eng. or Scien.	107	62	169	30%
Engineer/Scientist	165	94	259	47%
Senior Technician	8	4	12	2%
Technician	3	1	4	1%
Other	20	22	44	8%
	340	213	553	100%

$$x^2 = 5.5 \qquad p = .5$$

Table 4.6

Demographic Statistics

Highest Educational Degree Received by R&D

	Research	Development	Total	Percent
High School	5	0	5	1
Associate	5	4	9	2
Bachelor	179	121	306	55%
Masters	107	75	182	33%
Ph.D	26	4	30	5%
Post Doc	5	0	5	1%
Other	11	5	16	3%
	338	215	553	100%

$$x^2 = 16.4 \qquad p = .01$$

Table 4.7

Demographic Statistics

Education Degree Major by R&D

	Research	Development	Total	Percent
Electrical Engineering	125	61	186	34%
Aeronautical Engineering	42	37	79	15%
Mechanical Engineering	22	39	61	11%
Other Engineering	12	9	21	4%
Physics	61	11	72	13%
Math	18	4	22	4%
Computer Science	14	5	19	4%
Other Sciences	6	0	6	1%
Other (e.g., Management)	28	45	73	13%
Not Applicable	9	2	11	2%
	337	213	550	100%

Table 4.8

Demographic Statistics

Major Discipline by R&D

Discipline	Research	Development	Total
Engineering	201 (61.3%)	146 (67.2%)	347 (64.4%)
Sciences	99 (30.2%)	20 (9.5%)	119 (22.1%)
Management	28 (8.5%)	45 (21.3%)	73 (13.5%)
	328 (60.9%)	211 (39.1%)	539 (100%)

4.5 Data Collection Procedure

The two surveys were personally distributed to each individual participating in the study where ever possible. The first survey, distributed to all group members of selected units, obtained data on their perceptions of the contextual variables, organizational variables and information processing behaviors of their unit.[5] A second survey, administered to upper level management responsible for the unit, was designed to provide effectiveness measures of units participating in the study. The purpose of using a personal distribution method is essentially stated by Lempke and Mann (1976) in their study:

1. to maximize the response rate through personal encouragement of the subjects and by providing answers to questions of an administrative nature concerning the questionnaire; and

2. to obtain a "feel" for the R&D environment from which the data would come.

Respondents were instructed to complete the questionnaire independently within a specified amount of time so as to allow the

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[5] In several cases, the unit manager asked that only a percentage of the work unit be surveyed. In this case, the surveys were distributed on a random basis to the work unit members.

investigator to personnally retrieve them while at the site. Those respondents not completing the questionnaire in time to allow for a personal retrieval by the investigator were provided a pre-addressed envelope and asked to return the questionnaire by a "no later than" date. A final telephone call was made to those units who had not returned at least 50% of the surveys, three or four working days prior to the "no later than" date, encouraging them to respond. Since the unit of analysis is the organizational unit, individuals were able to maintain anonymity. However, surveys were numbered to allow identification of the unit from which a response came. Strict confidentially was maintained on the performance/effectiveness rating given a unit by the evaluators

4.6 Variable Measurement and Computation

Each variable shown in Figure 4.1 was subject to a factor (principal components) analysis using a varimax (orthongonal) rotation to obtain the factors or dimensions associated with a particular variable. All factors with eigenvalues of 1.0 or greater were examined and interpreted. Upon identification of a dimension, a reliability measure was calculated to assess the internal consistency of the items making up the scale. Unit scores for each dimension and

variable were computed as the mean of the values of the individual unit member scores. Figure 4.3 illustrates the data reduction procedures used in determining unit-level variable scores from the raw data collected from the sample population (n = 561).

Figure 4 3

Schematics Representing the Procedures Used in Computation of Variable Scores

| Factor Analysis of Major Variables Across Respondents | → | Interpretation of Major Variable Dimensions | → | Identification of Dimension Scales | → | Reliability Analysis of Item Scales | → | Computation of Variable Scores for Individuals | → | Computation of Variable Scores for Work Units |
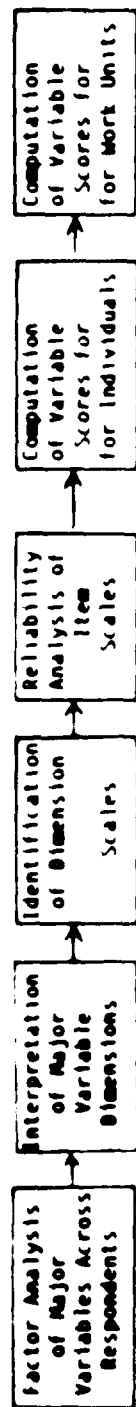
Process Used In the Computation of Work Unit Variable Scores form Work Unit Member Survey

| Factor Analysis of Effectiveness Measures Across Evaluators | → | Identification of Variable Dimensions | → | Reliability Analysis of Scale | → | Computation of Evaluators Scores for A Unit |

| Rank Correlation of Evaluators Score for Units | → | Computation of Unit Effectiveness Scores |
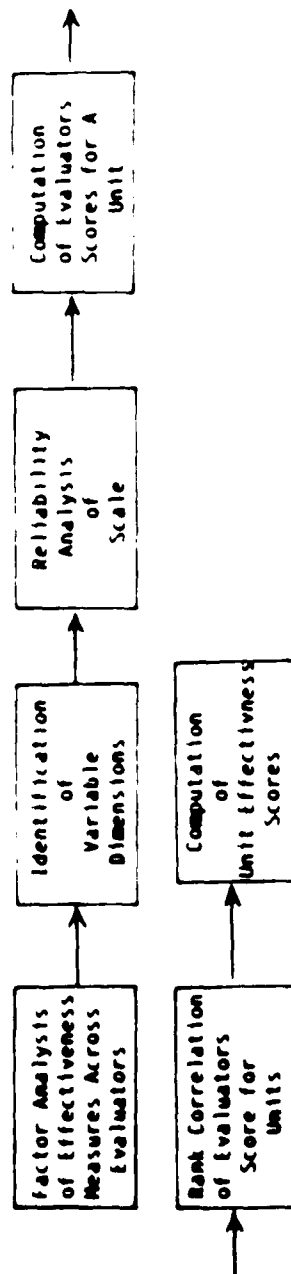
Process Used In the Computation of Work Unit Effectiveness Scores Across Evaluators

The results of the factor analysis performed on the variables shown in Figure 4.1 are summarized in Appendix E. The item abbreviations within each table are consistent with those used in Appendices A and B to allow for cross referencing. In general, the factor analysis proved confirmatory in nature with several exceptions. Two dimensions concerned with environmental uncertainty were identified: a change/complexity dimension, and a predictability/controllability dimension. The items making up unit structure were found to load on six factors, interpreted as: Centralization, Formalization, Participation in Decision Making, Impersonality, Specialization, and a Technology-type dimension. Subsequent analysis indicated that the impersonality and specialization scales had low reliabilities ($\alpha \approx .35$), and hence were not included in further analysis. Factor analysis identified two dimensions for each of the four information sources: an information requirements dimension and an information accessibility/quality dimension. Finally, a factor analysis of the multiple measures of unit effectiveness and performance provided one common dimension. That is, the principal component analysis extracted a single factor which accounted for 58% of the variances.

Table 4.9 summaries the results of the data reduction process
providing unit means, standard deviations, and scale reliabilities for
each variable dimension.

Table 4.9

Summary Statistics

R&D Work Unit Member Survey

Contextual Factors' Scales

Scale	Number of Items	Unit Level of Analysis (n = 80)		
		X	SD	alpha
Number of Task Exceptions	5	3.99	.54	.85
Analyzability of Task (reversed scored)	5	3.36	.67	.87
Change/Compexity of External Environment	4	4.13	.48	.80
Predictability of External Environment (reversed scored)	3	3.56	.54	.64
Dependence on Other Organizational Units	4	2.21	.58	.87
Other Organizational Units Dependence	4	2.16	.91	.95

Table 4.9 Continued

Summary Statistics

R&D Work Unit Member Survey

Organizational Factors' Scales

| | | Unit Level of Analysis (n = 80) | | |
Scale	Number of Items	X	SD	Cronbach alpha
Centralization	4	2.34	.69	.86
Formalization	4	2.20	.61	.84
Participation in Decision Making	3	2.13	.49	.68
Inter Unit Coordination	5	2.69	.47	.72

Table 4.9 Continued

Summary Statistics

R&D Work Unit Member Survey

Information Source Requirements and Accessibility/Quality Scales

		Unit Level of Analysis (n = 80)		
Scale	Number of Items	X	SD	Cronbach alpha
Information Requirements from:				
... Supervisor	2	3.63	.65	.84
... Unit Members	2	3.88	.62	.78
... Others in Organization	2	3.07	.47	.64
... External Sources	2	3.07	.56	.75
ccessability/Quality of Information from:				
... Supervisor	8	4.44	.37	.88
... Unit Members	8	4.39	.30	.85
... Others in Organization	8	3.61	.36	
... External Sources	8	3.36	.41	.86

4.7 Statistical Procedures for Hypothesis Testing

The statistical technique to be employed in testing the first three hypotheses will be a one way analysis of variance (ANOVA), since each of the hypotheses examines the difference in means between two groups ("treatments") and an interval variable ("effect"). In particular, the hypotheses concerning differences in mean values between research and development units for the contextual variables of organizational technology, environmental uncertainty, and inter-unit dependence are being examined. The ANOVA technique, commonly used and accepted in the analysis of cross-sectional data, requires that the k samples being tested be (1) independent, (2) normally distributed, and (3) have a common variance (Walepole and Myers, 1978). With regard to the first two assumptions, Cochran (1947) indicates

> "that no serious error is introduced by non normality in the significance levels of the F test or the two tailed t-test ... (and) as a rule, the tabular probability is an underestimate."

Cochran suggests that the assumption of independence is satisfied by "proper randomization." Cochran does point out that heterogeneity in variance may affect certain treatments or parts of the data to an unpredictable extent. To address the issue of common variance between the groups, Bartlett's Test for the homogeneity of variance will be

performed. If no serious violation of the three assumptions occurs, an F test is an appropriate statistic for comparing the equality of the group means.

Linear regressions were used to examine the relationship between the contextual variables of organizational technology, environmental uncertainty, inter unit dependence and information required from four (mutually exclusive) sources. In addition, regressions were generated for the situational variables of unit structure and inter-unit coordination on the accessability/quality of the information sources. Finally, a regression between the degree of fit (a function of the difference between information required from a source and the accessibility to and quality of the information source, and unit effectiveness was performed to test the congruency hypothesis of the Tushman/Nadler model. Bivariate scatter plots of the data sets were made to examine the overall pattern. Residual analyses were performed to assess the adequacy of the linear model. An F test provided the statistic for the significance of the linear relationship between variables.

A path analysis technique was used to analyze the data to examine the overall adequacy of the information processing model of organizational design and effectiveness within the R&D field setting.

Path analysis is a method of decomposing and aiding in the interpretation of linear relationships among a set of variables by assuming that (1) a weak causal ordering among these variables is known, or can reasonably be assumed, (2) the relationships among these variables are causally closed (Nie, Hull, Jenkins, Steinbrenner & Bent, 1975), and (3) the variables are measured on an interval scale (Karlinger and Pedhazur, 1973).

This study is designed to meet the assumptions of path analysis:

1. Necessary weak causal relationships among the variables were developed based on the Tushman and Nadler (1978) information processing model of organization design.

2. The causal relationships were grouped into a closed model, presented in Figure 4.4., and the recursive regression equations are identified in Table 4.10.

3. The basic assumptions of regression analysis were found to hold based on a residual analysis of the data.

Appendix D provides a brief discussion of the methodology of path analysis as used in this context. For a more complete and detailed presentation of the path analysis technique consult Wright (1934), Blalock (1961, 1971), Goldberger and Duncan (1973), Kerlinger and Pedhazur (1973), Duncan (1975), Heise (1975), Nie, Hull, Jenkins, Steinbrenner and Bent (1975), Cook and Campbell (1979), James, Mulaik and Brett (1982), and Asher (1983).

111
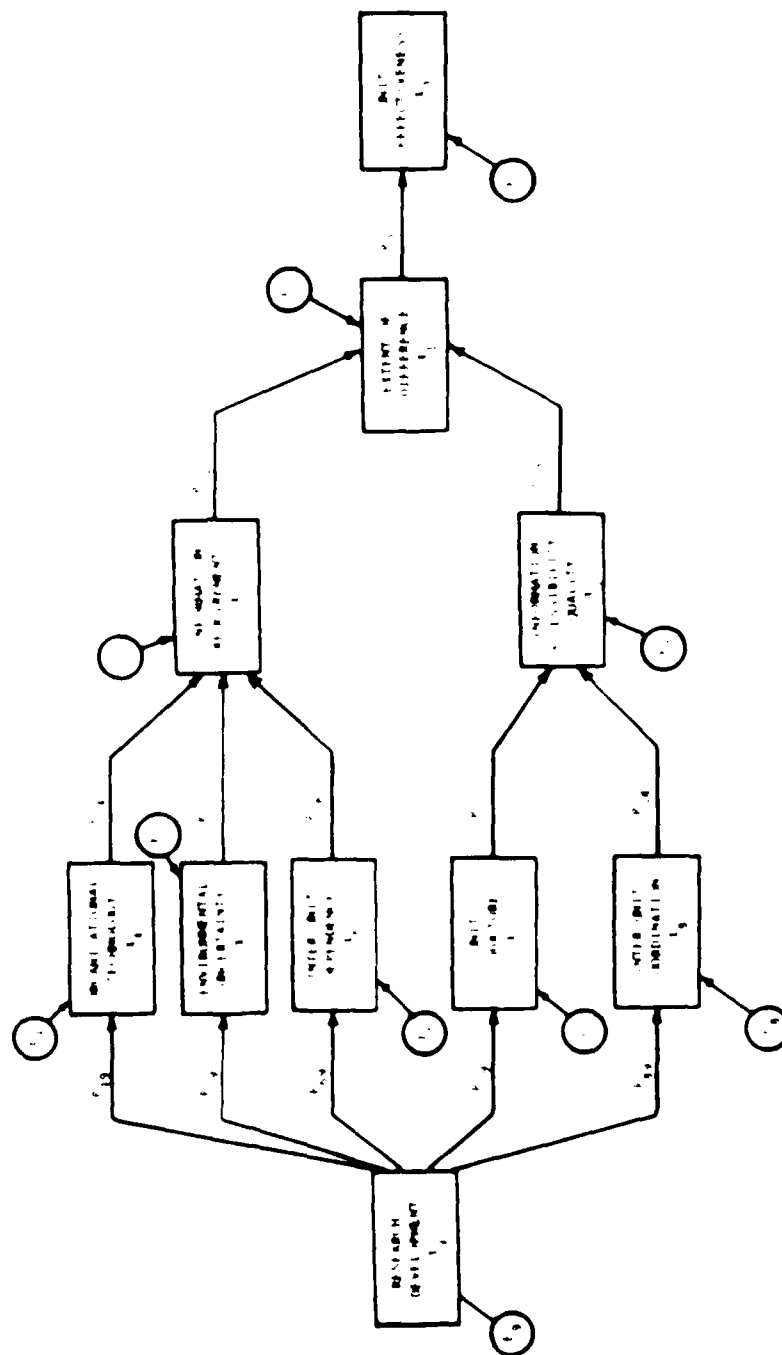
FIGURE 3.3

Table 4.10

Generalized Regression Equations for the Model Shown
in Figure 4.4

$$X_9 = E_9$$

$$X_8 = P_{89} + E_8$$

$$X_7 = P_{79}X_9 + E_7$$

$$X_6 = P_{69}X_9 + E_6$$

$$X_5 = P_{59}X_9 + E_5$$

$$X_4 = P_{49}X_9 + E_4$$

$$X_3 = P_{37}X_7 + P_{38}X_8 + E_3$$

$$X_2 = P_{24}X_4 + P_{25}X_5 + P_{26}X_6 + E_2$$

$$X_1 = P_{12}X_2 + P_{13}X_3 + E_1$$

$$X_0 = P_{01}X_1 + E_0$$

4.8 Assumptions

This research methodology employs assumptions similar to those used by Lemke and Mann (1976), Eschmann and Lee (1977), and Noyes and Parker (1978). They are:

1. The data collected are based on member perceptions. It is assumed that the data collected and the information obtained from it are representative of the relationships perceived to exist within the unit.

2. The sample of units is representative of those within organizations. This assumption is justified by the random selection of units within the organization.

3. Each respondent answered the questionnaire independently, and the responses are true reflections of the individual's feelings. This issue was addressed by ensuring the anonymity of the respondents.

The limitations associated with this study include:

1. This study focuses on the R&D process as conducted by randomly selected elements within the Military R&D Organizations. The implications of this research may be limited to this population.

2. The results of this study may be generalizable only to organizations conducting R&D within these Air Force Systems Command.

CHAPTER 5

RESULTS

5.1 Introduction

The hypotheses examined in this thesis are derived from an operationalization of the information processing model of organizational design and effectiveness proposed by Tushman & Nadler (1978) applied to a research and development field setting. Sections 5.2 to 5.10 review the hypotheses and the statistical evidence related to the specific relationships proposed by this model. Section 5.11 provides an overall assessment of the validity of the model, within this field setting, using a path analysis technique discussed in Chapter 4. The hypothesis testing and path analyses are performed at two levels of analysis: the variable (3rd order) level and the dimensional (2nd order) level.[6]

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[6] The derivation of the term 2nd and 3rd order come from the procedure used in developing subscales and scales. A 1st order analysis, the lowest possible level, would consist only of individual data items. A 2nd order or dimensional level analysis, consists of a number of items identified as a valid subscale by the factor analysis. A 3rd order analysis, uses dimensional subscales to form variable scales.

The confirmatory principal components and reliability analyses
discussed in Chapter 4 indicated that *several of the conceptual
dimensions* were not clearly identifiable within the subject population
and/or the dimensional subscales were not sufficiently reliable to be
included in further data analysis. In some cases, multiple
dimensions, such as in environmental change and complexity, were found
to load on a single factor. This resulted in a change to the variable
dimensions which, in turn, suggested that revisions to several of the
a priori hypotheses would be necessary to provide consistency with the
empirically based dimensional subscales.

The subsequent sections of this chapter follow the format of the
hypotheses set forth in Chapter 3, stating each hypothesis
(identifying revised hypotheses), with a discussion of the outcome of
the hypothesis test. In addition, for each hypothesis set, a Table is
provided consisting of the hypothesis being tested, the statistical
data used in testing the relationship, and a conclusion concerning the
outcome.

5.2 Effect of Research and Development on the Contextual Factors

The first three hypotheses examine the differences between
research and development groups on the contextual variables of

organizational technology, environmental uncertainty and inter-unit
dependence. Organizational technology was found to consist of two
dimensions: the number of exceptions associated with a task (often
referred to as task variety) and the analyzability of the task (that
is, the extent to which participants can follow an objective,
computational procedure to solve problems) (Witney, Daft and Cooper,
1983). Organizational technology, then, is defined by the average of
these factors. Environmental uncertainty was also found to have two
dimensions. The first is the extent to which the environment is
complex/dynamic. Complexity has to do with the number of factors in
the environment which impact the unit, while dynamism has to do with
the extent that these factors change over time. Although Duncan
(1972) found complexity and dynamism to be separate dimensions, the
factor analysis, discussed in Chapter 4, found complexity and dynamism
to form one dimension. The other dimension making up environmental
uncertainty is the extent to which the environment is predictable and
controllable. Similar to the complexity/dynamism dimension,
environmental predictability and controllability were proposed by
Brown and Schwartz (1983) as two distinct dimensions. However, the
factor analysis performed indicated only one dimension was present.
Hence, environmental uncertainty will be defined as the arranging of

these two factors. Inter unit dependence was found to have two dimensions based upon Thompson's (1967) interdependence conceptualization: the extent a unit is dependent upon other organizational units to perform work, and the degree to which other organizational units are dependent upon a unit to perform their work. As with organizational technology and environmental uncertainty, inter unit dependence will be determined by averaging of the two dimensions. Differences between research and development will be tested on the dimensional level, as well as on a variable level, for the contextual factors. Hypotheses related to the mean differences between research and development for the exceptions and analyzability dimensions of organizational technology are stated in Hypotheses 1a and 1b, respectively. Hypotheses involving mean differences between research and development for the complexity/dynamism and the predictability/controllability dimensions of environmental uncertainty are proposed in Hypothesis 2a and 2b, repectively. Hypotheses associated with mean differences between R&D for the inter-unit dependence dimensions are proposed in hypotheses 3a and 3b. Differences between research and development in mean values for the contextual variables of organizational technology, environmental uncertainty and inter unit dependence are proposed in Hypotheses 1c, 2c, and 3c, respectively.

5.2.1 Hypothesis Set 1: Effect of Research versus Development on Unit Technology

> **Hypothesis 1a**: The perceived number of task exceptions will be greater for research units than for development units.

Research units (n 42) averaged 4.11, compared to 3.42 for development units (n 38), on a 7 point Likert like scale for the exception dimension of organizational technology. The difference in means between the two groups was significant at the $p < .05$ level, indicating that research units perceive greater task exceptions or variety than do development groups. A test for homogeneity of variance did not yield results which suggest that the distributions between the groups was different for the exception dimension scores. Table 5.1a presents the analysis of variance used in testing Hypothesis 1a.

> **Hypothesis 1b**: The degree to which tasks are perceived as unanalyzable will be greater for research units than for development units.

Research units averaged 3.42, compared to 3.30 for development units, for the degree to which tasks are perceived as unanalyzable or unstructured. Although not statistically significant, the direction of the relationship was in the predicted direction. A test for homogeneity of variance did not yield results which suggest that the

distributions between the groups was significantly different for the analyzability dimension scores. Table 5.1b presents the analysis of variance results which suggest that hypothesis 1b is not supported.

Hypothesis 1c: The perception of non-routine technology will be greater for research units than for development units.

Research units averaged 3.77 compared to 3.58 for development units for the extent of non routine technology associated with their tasks. The analysis of variance, presented in Table 5.1c, does not support this hypothesis although the direction of the relationship is in the predicted direction. Furthermore, the F ratio of 2.41 is nearing significance at the $\alpha = .10$ level. A test for homogeneity of variance did not yield results suggesting a difference in distributions between research and development on technology scores.

Plotted in Figure 5.1 are the mean values for research and development in terms of Perrow's (1967) 2 dimensional graphical framework. The X and Y axes correspond to the analyzability and exception dimensions, respectively. The axis range corresponds to the range of the 7 point scale used in obtaining responses. From Figure 5.1 it is apparent that both research and development units perceive their organizational technology to be non-routine, although the

difference between research and development indicated by the figure was not statistically significant at α -.05 level. Table 5.2 summarizes the results of the statistical analyses performed on Hypotheses 1a, 1b, and 1c.

TABLE 5.1a

HYPOTHESIS SET 1

Analysis of Variance Table for Hypothesis 1a

HYPOTHESIS 1a: The perceived number of task exceptions will be
                greater for research units than for development
                units.

   INDEPENDENT VARIABLE: Research vs. Development

   DEPENDENT VARIABLE (Dimension): Number of Task Exceptions

ANALYSIS OF VARIANCE

SOURCE	df	SUM OF SQUARES	MEAN SQUARE	F-RATIO
BETWEEN GROUPS	1	1.23	1.23	4.35*
WITHIN GROUPS	18	22.12	.28	
TOTAL	19	23.35		

   CONCLUSION: Hypothesis 1a supported at α=.05 level

*p < .05

TABLE 5.1b

HYPOTHESIS SET 1

Analysis of Variance Table for Hypothesis 1b

HYPOTHESIS 1b: The degree to which tasks are perceived as
unanalyzable will be greater for research units than
for development units.

INDEPENDENT VARIABLE: Research vs. Development

DEPENDENT VARIABLE (Dimension): Degree Task is Unanalyzable

ANALYSIS OF VARIANCE

SOURCE	df	SUM OF SQUARES	MEAN SQUARE	F-RATIO
BETWEEN GROUPS	1	.33	.33	.7463
WITHIN GROUPS	18	34.62	.44	
TOTAL	19	34.95		

CONCLUSION: Hypothesis 1b not supported

TABLE 5.1c

HYPOTHESIS SET 1

Analysis of Variance Table for Hypothesis 1c

HYPOTHESIS 1b: The perception of non routine technology will be
greater for research units than for development units.

INDEPENDENT VARIABLE: Research vs. Development

DEPENDENT VARIABLE: Organizational Technology

ANALYSIS OF VARIANCE

SOURCE	df	SUM OF SQUARES	MEAN SQUARE	F-RATIO
BETWEEN GROUPS	1	.71	.71	2.41
WITHIN GROUPS	18	23.02	.30	
TOTAL	19	23.73		

CONCLUSION: Hypothesis 1c not supported
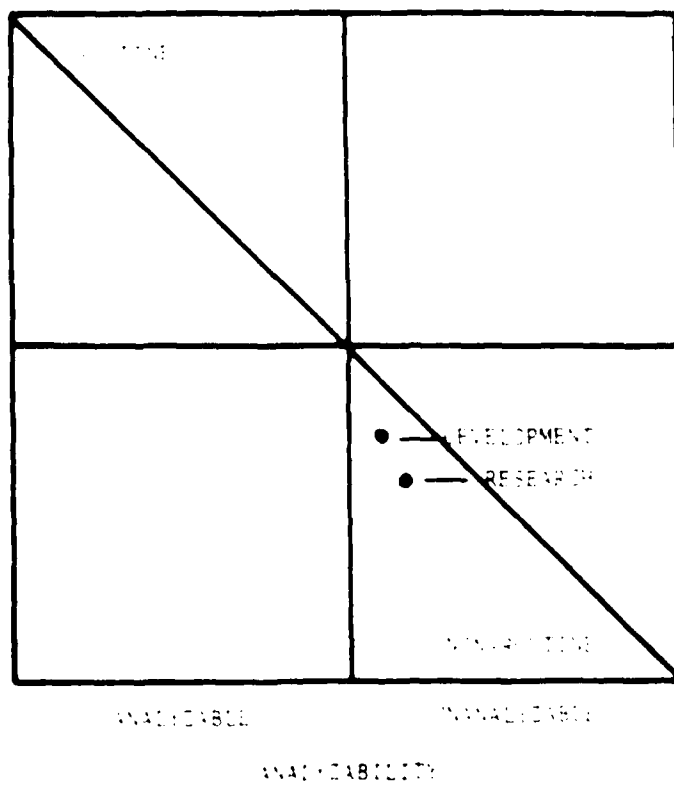
Table 5.2

Hypothesis Set 1

H_0 X_r X_d H_1 $X_r > X_d$ level .05

Analysis of Variance Results for Organization Technology X Research & Development

Dimension/Variable	Research Units (n = 42)		Development Units (n = 38)		F Ratio	F Probability	fail to reject/ reject H_0
	X_r	SD_r	X_d	SD_d			
1a. Exceptions	4.11	.57	3.86	.49	4.35	.04	reject
2a. Unanalyzability	3.42	.72	3.30	.60	.75	.39	fail to reject
1c. Organizational Technology	3.77	.59	3.58	.49	2.41	.12	fail to reject

5.2.2   Hypothesis Set 2: Effect of Research versus Development on
         Environmental Uncertainty

Hypothesis 2a: Development   units   will   perceive   their
environments to be more complex and dynamic than will research
units.

Development units (n=38) averaged 4.08, compared to 4.17 for

research units (n=42), on a 7 point likert like scale for the

complexity/dynamism dimension of environmental uncertainty.   The

difference in means between the two groups was not significantly

different.   Bartlett's homogeneity of variance did not yield results

which suggest that the complexity/dynamism distributions beween the

research and development are statistically different.   Table 5.3a

presents the analysis of variance table for Hypothesis 2a.

Hypothesis 2b: Development units will perceive their environments
to be less predictable and controllable than will research units.

Development units averaged 3.50, compared to 3.61 for research

units, which was not statistically significant.   Bartlett's test did

not suggest evidence to indicate a difference in variance for this

scale between research and development.   Table 5.36 provides the

analysis of variance table for hypothesis 2b.

Hypothesis 2c: Development units will perceive their environments to be more uncertain than will research units.

Development units averaged 3.79, compared to 3.89 for research on the environmental uncertainty variable. The difference in means between the two groups is not statistically significant. Table 5.3c provides the analysis of variance table for Hypothesis 2c. Figure 5.2 plots the mean values for the environmental uncertainty dimensions for research and development units. The perceived environment by both research and development units is one of uncertainty; that is, an environment that is complex/dynamic and unpredictable/uncontrollable. Table 5.4 summarizes the results of the statistical analysis performed on Hypotheses 2a, 2b and 2c.

TABLE 5.3a

HYPOTHESIS SET 2

Analysis of Variance Table for Hypothesis 2a

HYPOTHESIS 2a: Development units will perceive their environments to
be more complex and dynamic than will research units.

INDEPENDENT VARIABLE: Research vs. Development

DEPENDENT VARIABLE (Dimension):   Environmental Complexity/Dynamism

ANALYSIS OF VARIANCE

SOURCE	df	SUM OF SQUARES	MEAN SQUARE	F RATIO
BETWEEN GROUPS	1	.17	.17	.73
WITHIN GROUPS	18	17.81	.23	
TOTAL	19	17.98		

CONCLUSION: Hypothesis 2a not supported

TABLE 5.3b

HYPOTHESIS SET 2

Analysis of Variance Table for Hypothesis 2b

HYPOTHESIS 2b: Development units will perceive their environments to
be less predictable and less controllable than will
research units.

INDEPENDENT VARIABLE: Research vs. Development

DEPENDENT VARIABLE (Dimension): Environmental Unpredictability

ANALYSIS OF VARIANCE

SOURCE	df	SUM OF SQUARES	MEAN SQUARE	F-RATIO
BETWEEN GROUPS	1	.25	.25	.85
WITHIN GROUPS	18	22.95	.29	
TOTAL	19	23.20		

CONCLUSION: Hypothesis 2b not supported

TABLE 5.3c

HYPOTHESIS SET 2

Analysis of Variance Table for Hypothesis 2c

HYPOTHESIS 2c: Development units will perceive their environments to
be more uncertain than will research units.

INDEPENDENT VARIABLE: Research vs. Development

DEPENDENT VARIABLE (Dimension): Environmental Uncertainty

ANALYSIS OF VARIANCE

SOURCE	df	SUM OF SQUARES	MEAN SQUARE	F-RATIO
BETWEEN GROUPS	1	.21	.21	1.25
WITHIN GROUPS	18	12.90	.17	
TOTAL	19	13.11		

CONCLUSION: Hypothesis 2c not supported

PREDICTABILITY OF ENVIRONMENT
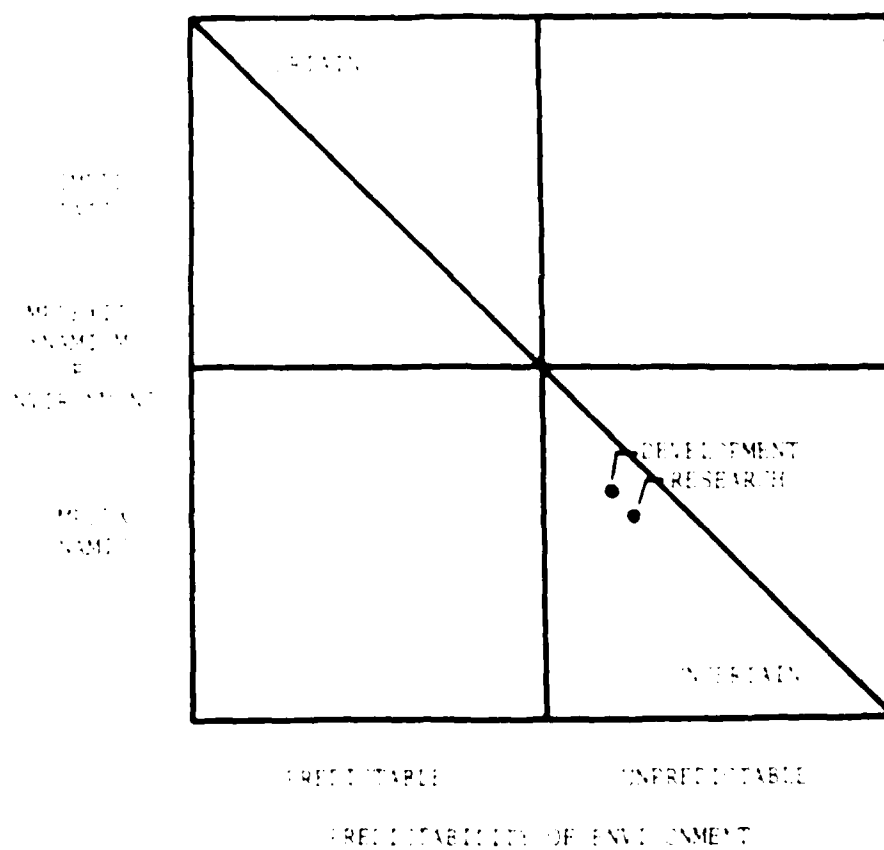
Table 5.4

Hypothesis Set 2

Analysis of Variance Results for Environmental Uncertainty x Research & Development

$H_o: X_r = X_d$ $H_1: X_r \neq X_d$ α level .05

Dimension/Variable	Research Units (n = 42)		Development Units (n = 38)		t Ratio	t Probability	Fail to reject/ reject H_o
	X_r	SD_r	X_d	SD_d			
*2a,b Complexity/Dynamism	4.17	.48	4.08	.48	.13	.40	Fail to reject
*2c,d Unpredictability	3.61	.51	3.50	.58	.85	.36	Fail to reject
2e Environmental Uncertainty	3.89	.41	3.79	.40	1.25	.27	Fail to reject

* Revised hypotheses based on factor analysis

5.2.3   Hypothesis Set 3: Effect of Research versus Development on
         Inter-unit Dependence

Hypothesis 3a: Development units will perceive greater
dependence on other organizational units than will research units.

Development units (n=38) averaged 3.24, compared to 2.08 for

research units (n = 42), on a 7 point Likert like scale for the

dimension "extent of dependence on other organizational units". The

analysis of variance table (Table 5.5a) shows an F ratio of 3.95,

indicating a significant difference at the .05 level. A test for

homogeneity of variance did not yield evidence suggesting different

distributions between the two groups. Hence, Hypothesis 3a was

supported at a level of $p = .05$.

Hypothesis 3b: Development units will perceive to a greater
extent that other units are dependent on them to accomplish work
objectives than will research units.

Development units averaged 2.65, compared to 1.72 for research units,

on the dimension "extent other units are dependent on your unit to

accomplish work". Table 5.5b provides the ANOVA results for this

hypothesis; the F ratio of 28.00 indicates a high degree of

significance. Bartlett's test for homogeneity of variance did not yield

results indicating that different distributions exist between the two

groups for this dimension. Hence, Hypothesis 3b was supported at a level

of $p \leq .01$.

Hypothesis 3c: Development units will perceive a greater degree of inter-unit dependence than will research units.

Development units averaged a value of 2.50 with a standard deviation of .61, compared with a mean of 1.90 and standard deviation of .48 for research units. Table 5.5c represents the ANOVA table for Hypothesis 3c, indicating an F ratio of 23.64 which is significant at the .01 level. Bartlett's test for the homogeneity of variance did not yield evidence suggesting that different distributions underlie the two groups. Plotted in Figure 5.3 are the mean values of the interdependence scores on a 2 dimensional grid, indicating that the mean values for the degree of interdependence for both research and development units fall within the relatively low area. However, a significant difference for the mean value of inter unit dependence does exist between research and development units. Table 5.6 summarizes the statistical analysis performed on Hypothesis Set 3.

TABLE 5.5a

HYPOTHESIS SET 3

Analysis of Variance Table for Hypothesis 3a

HYPOTHESIS 3a: Development units will perceive greater dependence on
other organizational units than will research units.

INDEPENDENT VARIABLE: Research vs. Development

DEPENDENT VARIABLE (Dimension): Dependence on Other
Organizational Units

ANALYSIS OF VARIANCE

SOURCE	df	SUM OF SQUARES	MEAN SQUARE	F-RATIO
BETWEEN GROUPS	1	1.30	1.30	3.95*
WITHIN GROUPS	18	25.65	.33	
TOTAL	19	26.95		

CONCLUSION: Hypothesis 3a supported at $\alpha = .05$ level

*$p < .05$

TABLE 5.5b

HYPOTHESIS SET 3

Analysis of Variance Table for Hypothesis 3b

HYPOTHESIS 3b: Development units will perceive to a greater degree
                that other organizational units are dependent on them
                to accomplish work objectives than will research
                units.

   INDEPENDENT VARIABLE: Research vs. Development

   DEPENDENT VARIABLE (Dimension):   Other Organizational
                                     Unit Dependence

ANALYSIS OF VARIANCE

SOURCE	df	SUM OF SQUARES	MEAN SQUARE	F-RATIO
BETWEEN GROUPS	1	17.19	17.19	28.00*
WITHIN GROUPS	18	47.89	.61	
TOTAL	19	26.95		

   CONCLUSION: Hypothesis 3b supported at $\alpha=.001$ level

*p < .001

TABLE 5.5c

HYPOTHESIS SET 3

Analysis of Variance Table for Hypothesis 3c

HYPOTHESIS 3c: Development units will perceive a greater degree of
inter unit dependence than will research units.

INDEPENDENT VARIABLE: Research vs. Development

DEPENDENT VARIABLE: Inter Unit Dependence

ANALYSIS OF VARIANCE

SOURCE	df	SUM OF SQUARES	MEAN SQUARE	F RATIO
BETWEEN GROUPS	1	6.98	6.98	23.64*
WITHIN GROUPS	18	23.05	.30	
TOTAL	19	26.95		

CONCLUSION: Hypothesis 3c supported at $\alpha=.001$ level

*p < .001

FIGURE

DEPENDENCE ON OTHER
ORGANIZATIONAL UNITS
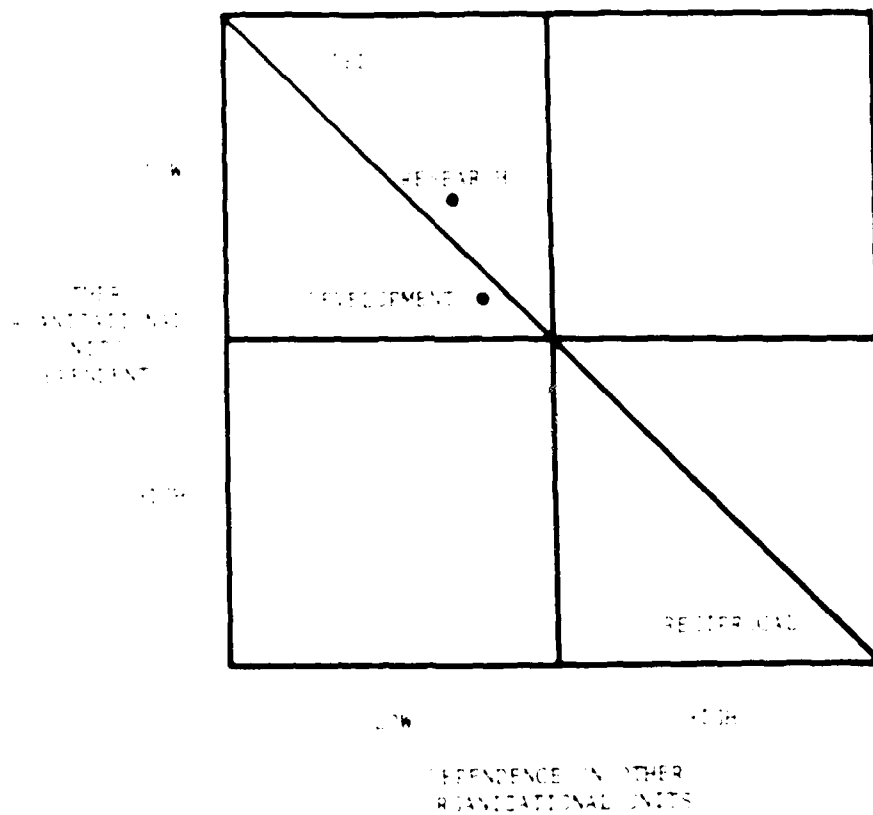
Table 5 6

Hypothesis Set 3

$H_0: X_r = X_d$ $H_1: X_r \neq X_d$ level .05

Analysis of Variance Results for Inter Unit Dependence X Research & Development

Dimension/Variable	Research Units (n = 42)		Development Units (n = 38)		F Ratio	F Probability	fail to reject/ reject H_0
	X_r	SD_r	X_d	SD_d			
3a Dependence on Other Units	2 08	52	2 34	63	3 95	05	reject
3b Other Units Dependent	1 72	69	2 65	88	28 00	01	reject
3c Inter Unit Dependence	1 90	48	2 50	61	23 64	01	reject

5.3 Contextual Variables and Organizational Unit Information Source Requirements

The following hypotheses explore the relationship of the contextual variables of organizational technology, environmental uncertainty, and inter unit dependence with information source requirements. Information source requirements are categorized by supervisor/manager, unit or group members, other organizational members (outside of unit), sources external to the organization, and total information source requirements. Regression analyses are performed to examine and test the significance of the relationships. Each of the contextual dimensions and variables are regressed on each of the five information sources (dependent variable). Hence, for each contextual dimension or variable, a set of five regression equations are generated.

Following the format established in the first three hypothesis sets, the first two hypotheses in each of the following hypotheses sets concern the dimensions of the contextual variable and the third hypothesis is the contextual variable itself.

5.3.1 Hypothesis Set 4: Relationship Between Organizational Unit Technology and Unit Information Source Requirements.

5.3.1.1 **Hypothesis 4a**: The number of task exceptions will be positively related to information source requirements.

5.3.1.2 **Hypothesis 4b**: The degree of task analyzability will be negatively related to information source requirements.

5.3.1.3 **Hypothesis 4c**: Non-routine technology will be positively related to information source requirements.

The regression equations in Table 5.7 suggest that no significant relationship exists between the dimensions of organizational technology and information source requirements. Scattergrams of the independent and dependent variable do not suggest any discernible relationship.

Table 5.1

Hypothesis Set 4

Tests for Significant Contributions of Organizational Technology on Information Source Requirements

Model: $Y_1 = B_0 + B_{51} X_{51} + e$

Where:

Y1 - Information Required from Supervisor/Manager
Y2 - Information Required from Group Members
Y3 - Information Required from Organizational Services
Y4 - Information Required from Sources Outside of Organization
Yt - Information Required from All Sources

Y41 - Unit's Environmental Complexity/Dynamism Subscale (Dimension)
Y42 - Unit's Environmental Unpredictability/Uncontrollability Subscale (Dimension)
Y40 - Unit's Environmental Uncertainty

Hypothesis 4a: Relationship between Number of Task Exceptions (X_{41}) and Information Source Requirements

Model	B_0	B_{51}	R	R^2	F Value	F Significance
Y1	3.80	.04	.035	.001	.10	.76
Y2	3.57	.08	.069	.005	.38	.54
Y3	2.71	.09	.105	.011	.88	.35
Y4	3.56	.12	.118	.014	1.10	.30
Yt	3.41	.001	.002	.001	.001	.99

Table 5 / Continued

Hypothesis Set 4

<u>Hypothesis 4b</u>   Relationship between Task Unanalyzability (X_{4c}) and Information Source Requirements

Model	B_0	B_{4c}	R	R^2	F Value	F Significance
Y_1 =	4.10	.13	.143	.020	1.62	.21
Y_2 =	4.11	.07	.015	.006	.44	.51
Y_3 =	2.98	.03	.036	.001	.10	.75
Y_4 =	3.04	.001	.008	.001	.01	.94
Y_t =	3.56	.04	.072	.005	.41	.52

<u>Hypothesis 4c</u>   Relationship between Organizational Technology (X_{40}) and Information Source Requirements

Model	B_0	B_{40}	R	R^2	F Value	F Significance
Y_1 =	4.08	.12	.104	.011	.86	.36
Y_2 =	3.93	.01	.011	.001	.01	.92
Y_3 =	2.84	.06	.074	.006	.43	.51
Y_4 =	3.27	.05	.053	.003	.22	.64
Y_t =	3.53	.03	.043	.002	.14	.70

5.3.2   Hypothesis <u>Set 5</u>:   Relationship Between Environmental
         Uncertainty and Unit Information Source Requirements

Hypothesis 5a: Environmental complexity/dynamism will be
positively related to <u>extra organizational</u> information source
requirements.

The environmental complexity/dynamism dimension was found to

effect significantly the information source requirements for the

Supervisor/ Manager, Group Members and External Information sources at

the significance levels of .01, .02, and .02, respectively (Table

5.8). The relatively high significance of these three relationships

resulted in the information requirements from all sources being

significant at the .01 level of significance.

Hypothesis 5b: Environmental predictability/controllability will
be negatively related to <u>extra-organizational</u> information source
requirements.

Regression analyses between environmental predictability/control-

lability and information source requirements indicated that a

significant relationship does exist (p = .05); however, in a direction

opposite than hypothesized. An explanation for this may be that if an

environment is perceived as unpredictable and uncontrollable,

information may be of little or no use. Further, such an environment

will result in less information required from external sources since

the information is equivocal.

Hypothesis 5c: Environmental uncertainty will be positively related to extra-organizational information requirements.

Regression equations were not statistically significant for information source requirements regressed on environmental uncertainty. This result can be explained if one recalls that the two dimensions (complexity/dynamism and unpredictability/uncontrollability) were found to be related to information source requirements in opposite ways. The net result for the environmental uncertainty variable, of course, will be a "wash" effect. Table 5.8 presents the results of the regression analysis performed for Hypothesis Set 5.

Table 5 8

Hypothesis Set 5

Tests for Significant Contributions of Environmental Uncertainty on Information Source Requirements

$$\text{Model} \quad Y_1 \quad B_0 + B_{51} X_{51} + \cdots$$

Where:

Y_1 = Information Required from Supervisor/Manager

Y_2 = Information Required from Group Members

Y_3 = Information Required from Organizational Services

Y_4 = Information Required from Sources Outside of Organization

Y_t = Information Required from All Sources

X_{51} = Unit's Environmental Complexity/Dynamism Subscale (Dimension)

X_{52} = Unit's Environmental Unpredictability/Uncontrollability Subscale (Dimension)

X_{50} = Unit's Environmental Uncertainty

*Hypothesis 5a. Relationship between Complexity/Dynamism (X_{51}) and Information Source Requirements

Model	B_0	B_{51}	R	R^2	t Value	t Significance
Y_1	2 04	39	284	081	6 84	01
Y_2	2 52	33	252	064	5 30	02
Y_3	2 73	08	085	007	57	45
Y_4	1 79	31	262	069	5 74	02
Y_t	2 27	28	325	106	9 21	01

*Revised hypothesis

Table 5.8 (continued)

Hypothesis Set 5

*Hypothesis 5b: Relationship between Unpredictability/Uncontrollability (X_{52}) and Information Source Requirements

Model	B_0	B_{52}	R	R^2	F Value	F Significance
Y_1	4.12	.14	.114	.013	1.04	.31
Y_2	4.01	.05	.041	.002	.11	.68
Y_3	3.20	.04	.045	.002	.16	.69
Y_4	3.87	.23	.211	.047	3.87	.05
Y_5	3.82	.11	.152	.023	1.84	.18

*Hypothesis 5c: Relationship between Environmental Uncertainty (X_{50}) and Information Source Requirements

Model	B_0	B_{50}	R	R^2	F Value	F Significance
Y_1	3.08	.14	.090	.008	.64	.43
Y_2	3.20	.18	.117	.013	1.07	.30
Y_3	3.98	.02	.020	.001	.03	.86
Y_4	3.02	.01	.009	.001	.01	.94
Y_c	3.07	.09	.089	.008	.63	.43

*Revised hypothesis

5.3.3 Hypothesis Set 6: Relationship Between Inter Unit Dependence and Information Source Requirements

This hypothesis set explores the relationship between the degree of inter unit dependence and the impact on information source requirements. The basic proposition underlying these hypotheses is that greater inter unit dependence should require greater amounts of inter unit information requirements.

Hypothesis 6a: Dependence on other organizational units will be positively related to inter-unit information source requirements.

The equations generated by regressing information source requirements on the "dependence on other organizational units" dimension resulted in two statistically significant relationships. Inter unit information requirements were found to increase with increasing degrees of inter unit dependence, significant at less than .01 level, supporting hypothesis 6a. However, the significant relationship between inter unit dependence and extraorganizational information source requirements was unexpected. The expectation was for no significant difference in extra organizational information requirements. One explanation for this relationship may be that if a unit is dependent on other organizational units, it is likely that the unit is dependent on other organizations as well.

Hypothesis 6b: The perception by a unit that other organizational units are dependent on it will be positively related to that units **inter-unit** information source requirement.

Two statistically significant relationships were found in regressing information source requirements on the "other units dependent" dimension. Inter unit information requirements were found to increase with increasing degrees of "other units dependent," supporting Hypothesis 6b at the .01 level of significance. The second (and unexpected and **negative**) relationship was found between increasing degrees of "other units dependent" and information required from the unit supervisor/manager (significant at .01 level). That is, increasing degrees of "other units dependent" is **positively** related to inter unit information requirements and **negatively** related to intra unit information requirements. This result suggests that individual unit members may be interacting directly with other organizational units. By this interaction, members may be responding to the needs of other units and do not require information from their own group members to perform their work.

Hypothesis 6c: Inter--unit dependence will be positively related to **inter-unit** information source requirements.

Inter unit dependence, defined by two dimensions, was found to have a statistically significant relationship with inter-unit information requirements (at < .01 level), supporting Hypothesis 6c.

In addition, a significant positive relationship (.02 level) with extra organizational information requirements (due to the "dependence on other units" dimension) was found, and a near significant (.06 level) negative relationship with supervisor/manager information requirements was indicated. Table 5.9 presents the results of the regression analyses performed in testing this Hypothesis Set 6.

Table 5.9

Hypothesis Set 6

Tests for Significant Contributions of Inter Unit Dependence on Information Source Requirements.

Model $Y_i = B_o + B_{b1} X_{b1} + \cdots$

Where:

Y_1 - Information Required from Supervisor/Manager
Y_2 - Information Required from Group Members
Y_3 - Information Required from Organizational Services
Y_4 - Information Required from Sources Outside of Organization
Y_t - Information Required from All Sources

X_{b1} - Dependence on Other Organizational Units Subscale (Dimension)
X_{b2} - Other Organizational Unit's Dependence Subscale (Dimension)
X_{b0} - Inter Unit Dependence Scale (Variable)

Hypothesis 6a: Relationship between Dependence on Other Organizational Units (X_{b1}) and Information Source Requirements

Model	B_0	B_{b1}	R	R^2	F Value	F Significance
Y_1	3.54	.04	.033	.001	.09	.77
Y_2	3.14	.06	.061	.004	.29	.59
Y_3	2.46	.27	.340	.116	10.21	.01
Y_4	2.20	.40	.410	.168	15.79	.01
Y_t	2.99	.19	.276	.076	6.45	.01

Table 5 4 (continued)

Hypothesis Set 6

Hypothesis 6b Relationship between Other Organizational Units Dependence (A_{b2}) and Information Source Requirements

Model	B_0	B_{b2}	N	R^2	F Value	F Significance
Y_1	4 10	.22	305	092	1 97	01
Y_2	4 17	.13	192	037	2 98	09
Y_3	2 70	.17	334	112	9 80	01
Y_4	2 97	.04	072	005	40	53
Y_t	3 48	.03	074	006	43	51

Hypothesis 6c Relationship between Inter Unit Dependence (A_{b0}) and Information Source Requirements

Model	B_0	B_{b0}	N	R^2	F Value	F Significance
Y_1	4 11	.22	208	043	3 54	06
Y_2	4 13	.11	112	013	1 00	32
Y_3	2 40	.31	407	166	15 49	01
Y_4	2 58	.22	247	061	5 08	02
Y_5	3 30	.05	076	005	46	50

5.4 Organizational Design and the Accessibility and Quality of Information Sources

The following two sets of hypotheses explore the relationship between characteristics of the organizational design and the accessibility/quality of information sources. Accessibility and quality of an information source were found to form a common dimension which will be used in this study as the operationalization of information processing capability within the Tushman/Nadler (1978) model. That is, high accessibility/quality associated with an information source implies high information processing potential, while an inaccessible/low quality information source suggests low information processing potential. Organizational variables proposed by the Tushman/Nadler model which influence information processing capability are the structure of the unit, and the inter-unit coordination mechanisms used within the organization to integrate (control) the activities of the units. Unit structure, in this study, was found to have three discernible dimensions: extent of centralization (where legimate decision making authority is located within the unit), extent of formalization (degree written rules, policies and procedures exist for accomplishing work) and extent of participation in decision making (degree unit members have input in decision making process). The unit structure dimensions were found to

combine to form an organic mechanistic continuum for unit structure. That is, an organic structure is one that is decentralized, has low formalization, and high participation in decision making. A mechanistic structure is one characterized by high centralization, high formalization, and little participation in the decision process. The second organizational variable is extent of inter-unit coordination. Only one dimension was found to exist for this variable. Items used in measuring the extent of inter-unit coordination include: the degree to which rules/procedures are used to coordinate units, the degree to which plans/schedules are employed to coordinate units, and the degree to which lateral relations are used to coordinate unit activities. Regression analysis was used to determine the significance of the relationships between the organizational factors and the accessibility/quality of information sources.

5.4.1 Hypothesis Set 7: Relationship Between Unit Structure and the Accessibility/Quality of Information Sources

The three dimensions defining unit structure are measured in terms of increasing degrees of unit centralization and formalization, and decreasing degrees of participation in decision making. That is, unit structure is measured in terms of increasing degrees of mechanization.

Hypothesis 7a: The extent of centralization within a unit
structure will be negatively related to the
accessibility/quality of intra-unit information sources.

The regression of information accessibility/quality on the

centralization dimension of unit structure proved significant for two

sources: Supervisor/Manager (.003 level) and Group Members (.024

level). Hypothesis 7a is supported, suggesting that higher degrees of

centralization will result in lower degrees of accessibility/quality

of intra-unit information sources

Hypothesis 7b: The extent of formalization within a unit
structure will be negatively related to the accessibility/quality
of intra-unit information sources.

Regression analysis did not indicate a significant relationship

with accessibility/quality for any information source. Plots of

formalization against information source accessibility/quality did not

indicate any relationship.

Hypothesis 7c: The extent of participation in decision making
will be positively related to the accessibility/quality of
intra-unit information sources.

Regression analysis indicates strong relationships between this

dimension and the accessibility/quality of all information sources

(all at < .01 level of significance). Greater participation in the

unit decision making process by members will result in greater
perception of extra unit information source accessibility/quality as
well as intra unit information source accessibility/ quality.

Hypothesis 7d: The more mechanistic a unit structure, the less
the perceived accessibility/quality of intra-unit information
sources.

Regression equations for information accessibility/quality on unit
structure proved significant for two sources: Supervisor/Manager
(.004 level) and Group Members (.008 level). That is, mechanistic
unit structures had lower perceptions of information source
accessibility/quality than did organic structures. Hence, Hypothesis
7d is supported. Table 5.10 presents the regression analysis results
used in testing Hypothesis Set 7.

Table 5.10

Hypothesis Set 1

Tests for Significant Contributions of Unit Structure on Accessibility/Quality of Information Sources

$$\text{Model} \quad Y_j = B_0 + B_{j1} X_{j1} + \epsilon$$

Where:

Y_1 = Accessibility/Quality of Information from Supervisor/Manager
Y_2 = Accessibility/Quality of Information from Group Members
Y_3 = Accessibility/Quality of Information from Organizational Services
Y_4 = Accessibility/Quality of Information from Sources Outside of Organization
Y_t = Accessibility/Quality of Information from All Sources

X_{j1} = Centralization Subscale (Dimension)
X_{j2} = Formalization Subscale (Dimension)
X_{j3} = Participation in Decision Making Subscale Reversed Scored (Dimension)
X_{j0} = Unit Structure (Variable)

Hypothesis 1a Relationship between Centralization Dimension (X_{j1}) and Accessibility/Quality of Information Sources

Model	B_0	B_{j1}	R	R^2	F Value	F Significance
Y_1	4.88	.11	.324	.105	9.15	.003
Y_2	4.61	.11	.252	.064	5.31	.024
Y_3	3.82	.08	.156	.024	1.93	.168
Y_4	3.38	.01	.017	.001	.02	.881
Y_t	4.19	.09	.225	.051	4.17	.045

Table 5.10 Continued

Hypothesis Set 1

Hypothesis 1b. Relationship between Formalization Dimension (X_{12}) and Accessibility/Quality of Information Sources

Model	B_0	B_{12}	R	R^2	t Value	t Significance
Y_1	4.33	.05	.076	.006	.46	.50
Y_2	4.21	.05	.106	.011	.88	.35
Y_3	3.47	.07	.111	.012	.98	.33
Y_4	3.07	.13	.199	.039	3.20	.08
Y_t	3.78	.07	.158	.025	1.99	.16

Hypothesis 1c. Relationship between Participation in Decision Making Dimension (X_{13}) and Accessibility/ Quality of Information Sources Reversed Scored

Model	B_0	B_{13}	R	R^2	t Value	t Significance
Y_1	5.21	.39	.52	.27	29.21	.001
Y_2	5.16	.36	.59	.35	41.10	.001
Y_3	4.22	.28	.39	.15	13.93	.001
Y_4	3.91	.26	.31	.10	8.44	.005
Y_t	4.64	.32	.55	.31	34.69	.001

Table 5.10 Continued

Hypothesis Set /

Hypothesis /g Relationship between Mechanistic Unit Structure Variable (X_{10}) and Accessibility/Quality of Information Sources

Model	B_0	B_{10}	R	R^2	F Value	F Significance
Y_1 = =	5.04	26	321	103	8.95	004
Y_2 = =	4.27	20	295	087	7.43	008
Y_3 = =	3.47	14	171	029	2.35	129
Y_4 = =	3.07	03	033	001	09	769
Y_x = =	4.31	16	246	060	5.02	R20

5.4.2   Hypothesis   Set   8:   Relationship   Between   Inter Unit
         Coordinating   Mechanisms   and   Accessibility/Quality   of
         Information Sources

Hypothesis Set 8 consists of one hypothesis which examines the relationship between extent of inter unit coordination and accessibility/quality of extra unit information sources. The inter unit coordination measure is scored on the basis of an increasing reliance on coordinating mechanisms to integrate the activities of organizational units.

Hypothesis 8: The extent of inter-unit coordination will be positively related to the accessibility/quality of inter-unit information sources.

Inter unit coordination had no significant relationship to the accessibility/quality of any information source. Scatter plots of inter unit coordination by information source did not identify any discernible relationship. Table 5.11 summarizes the regression results used in testing Hypothesis 8.

Table 5 11

Hypothesis Set B

Tests for Significant Contributions of Inter Unit Coordination on Accessibility/Quality of Information Sources

Model $Y_1 = B_0 + B_{B1} X_{B1} + \ldots$

Where:
Y_1 = Accessibility/Quality of Information from Supervisor/Manager
Y_2 = Accessibility/Quality of Information from Group Members
Y_3 = Accessibility/Quality of Information from Organizational Services
Y_4 = Accessibility/Quality of Information from Sources Outside of Organization
Y_c = Accessibility/Quality of Information from All Sources

X_{B0} = Extent of Inter Unit Coordination Scale (Variable)

Hypothesis B: Relationship of Inter Unit Coordination and Accessibility/Quality of Information Sources

Model	B_0	B_{B0}	R	R^2	t Value	t Significance
Y_1	4.11	.12	.155	.024	1.92	.17
Y_2	4.33	.02	.036	.001	.10	.75
Y_3	3.78	.06	.080	.006	.51	.48
Y_4	3.67	.12	.131	.018	1.41	.24
Y_c	3.96	.000	.010	.000	.01	.91

5.5 Hypothesis Set 9: Unit Effectiveness as a Function of the Difference Between Information Source Requirements and the Accessibility/Quality of Information Sources

The underlying concept between the Tushman/Nadler model is that organizational or unit effectiveness can be obtained by matching unit information requirements to the information processing capabilities of the unit. When a unit's information requirements exceed it's capabilities, insufficient information exists for the unit to perform it's function (e.g., decision making or problem-solving), resulting in less unit effectiveness. Likewise, when information processing capabilities exceed requirements, non-relevant information may be processed by the unit, resulting in inefficiences or, perhaps worse, disruption of the functioning of the unit, again resulting in less unit effectiveness. The Tushman/Nadler model suggests that a unit will perform most effectively when its information processing requirements are equivalent to (or "match") its information processing capabilities. The following hypothesis explores this concept by examining the relationship between a unit effectiveness measure and the difference between the unit's information source requirements and the corresponding information source's accessibility/quality. Effectiveness measures were obtained for each unit by upper levels of management, where each unit was assessed by a minimum of two

evalulators. Kendall rank correlation tests were performed to determine if units were ranked similarly by the evaluators, and indicated a high degree of evaluator consistency (.05 or better level of significance). In addition, an ANOVA was performed across organizations which indicated that a roughly common mean and variance for unit effectiveness scores existed.

Hence, effectiveness scores for a unit were calculated by taking the average of the evaluator's scores. Effectiveness scores were normalized to a scale having a mean of 100. The range on this normalized scale was 79 to 118.

Hypothesis 9: Unit effectiveness will be positively related to those units with minimal difference between information source requirements and the accessibility/quality of information sources.

Hypothesis 9 suggests that the effectiveness function is similar to the function shown in Figure 5.4. That is, higher unit effectiveness is expected for units "fitting" information source requirements to the accessibility/ quality of the information sources. Scatter plots of the empirical data indicated that the range of difference on the "degree of difference" scale was restricted to roughly 16% of the scale (indicated by the vertical lines on Figure 5.4), with only about 15% of units reporting requirements exceeding

the accessibility/quality of a source. With such a small range, no curvilinear relationship was discernible. A regression analysis was performed using the absolute value of the "degree of difference" scale.

By taking the absolute value of the "degree of difference" scale, an implicit assumption is being made that the effectiveness function is symmetric about the mid point (i.e., where "requirements - capabilities") of this scale. The rationale in using an absolute value for the "degree of difference" measure is derived directly from the Tushman and Nadler model in that they propose that organizations having either excessive information processing requirements or excessive information processing capabilities will be less effective. In organizational units with excessive requirements, the information needed to reduce uncertainty to an acceptable level so that the unit can perform its function (e.g., problem solving or decision making) is not adequate. Organizations with excessive information processing capabilities, the model suggests, will result in extraneous information being processed for the unit's task, resulting in a degradation of unit effectiveness. However, in the data collected in this study, nearly 85% of the units reported "capabilities exceeding requirements" suggesting that we are primarily examining only the left side of the scale mid point (see Figure 5.4).

FIGURE - 4

HYPOTHESIS 2 ILLUSTRATED IN GRAPHICAL FORM
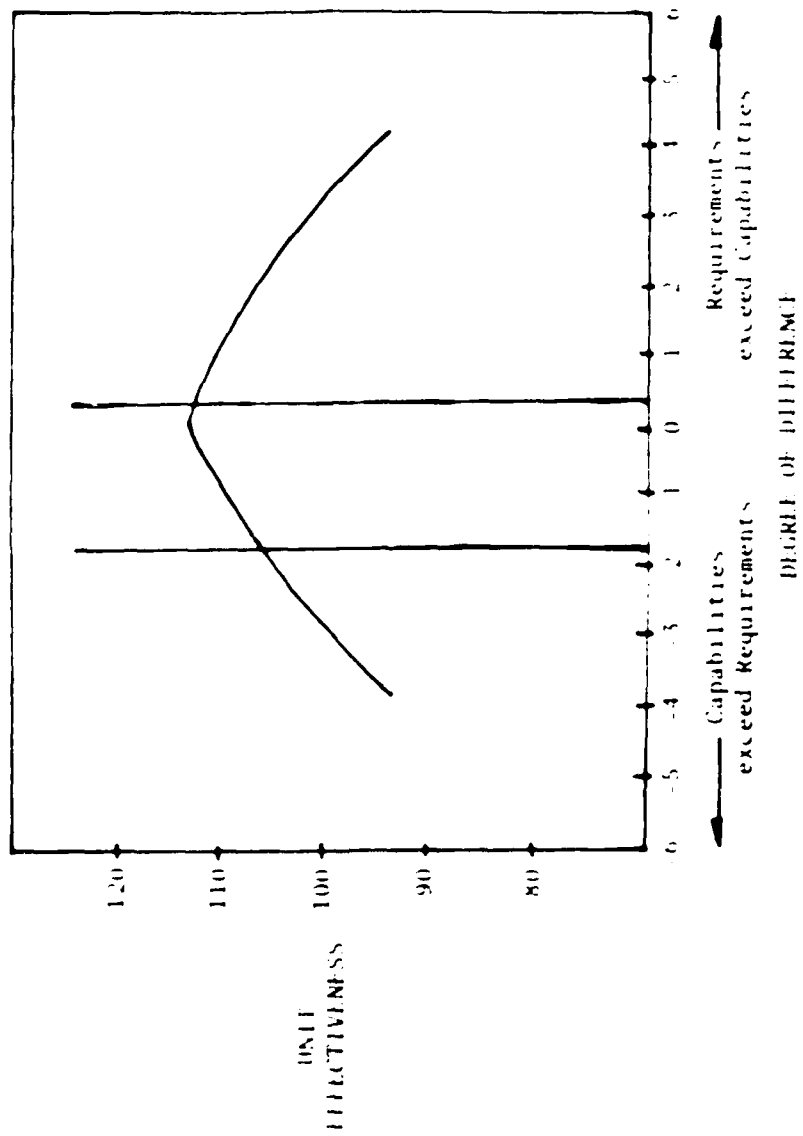
Regression equations performed by regressing unit effectiveness on the absolute value of the "degree of difference" scale indicated a negative, significant relationship (.02 level) for the Supervisor/Manager Information Source, and a near significant relationship (.07 level) for group members (Table 5.12). That is, units having information requirements approximately equivalent to the accessibility/quality of information from the Supervisor/Manager were more effective than those units having a difference between the requirements and accessibility/quality scales. Hence, Hypothesis 9 was, at best, only partially supported by the data; however, it should be noted that the restriction of range on the "degree of difference" scale does not provide for adequate testing of this hypothesis.
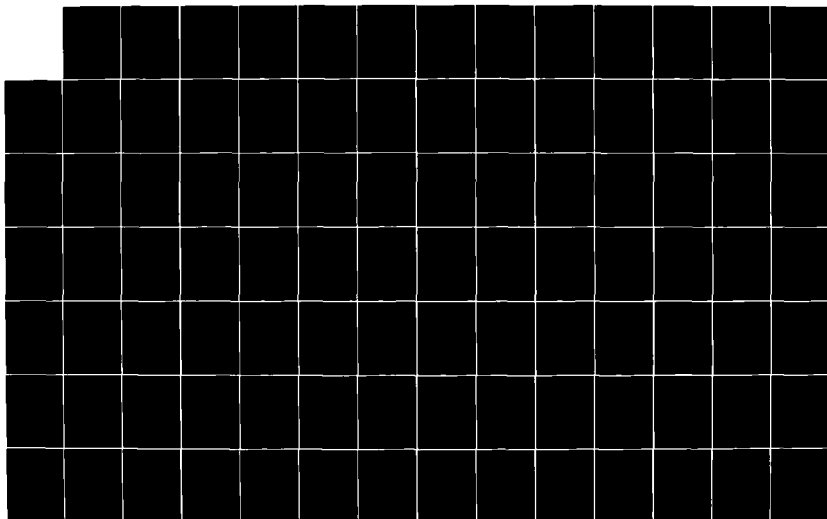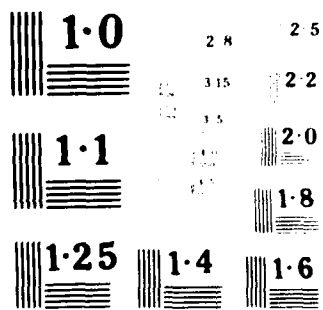
Table 5.12

Hypothesis Set 9

Tests for Significant Contributions of Matching Information Source Requirements to Information Source Accessibility/Quality on Unit Effectiveness (Congruency Hypothesis)

Model: $Y_1 = B_0 + B_{11} X_{11} + e$

Where: Y_0 = Unit Effectiveness

X_{11} = Absolute Value of the Difference between Information Required of Manager and Accessibility/Quality of Information from Manager

X_{12} = Absolute Value of the Difference between Information Required of Group Members and Accessibility/Quality of Information from Group Members

X_{13} = Absolute Value of the Difference between Information Required of Organizational Sources and Accessibility/Quality of Information from Organizational Sources

X_{14} = Absolute Value of the Difference between Information Required of Outside Sources and Accessibility/Quality of Information from Outside Sources

X_{10} = Absolute Value of the Difference between Information Required of all Sources and Accessibility/Quality of Information from all Sources

Model		B_0	B_{11}	R	R^2	F Value	F Significance
for X_{11}	Y_0 =	103.89	4.45	.269	.012	6.00	.02
for X_{12}	Y_0 =	102.77	4.47	.203	.042	3.41	.01
for X_{13}	Y_0 =	98.16	2.88	.123	.015	1.17	.28
for X_{14}	Y_0 =	98.54	2.52	.108	.012	.90	.35
for X_{10}	$\overline{Y}_0$ =	100.43	.14	.028	.001	.06	.81

5.6 Summary of Hypothesis Tests

Table 5.13 presents a summary of the results of the hypothesized relationships as proposed in the operationalization of the Tushman and Nadler (1978) information processing model of organizational design and effectiveness (Figure 4.1). Hypotheses examining the notion that research and development groups differ on several dimensions were supported; particularly strong were the differences reported in inter-unit dependence. Hypothesized relationships, derived from the Tushman/Nadler model, and examined at the variable level (denoted by asterisks in Table 5.13) were not generally supported. The non-significant results may be attributed to the restricted range found on many of the variables. However, a number of significant relationships were found at the dimensional level of analysis. The next chapter reviews the overall adequacy of the information processing model in this setting using a path analysis technique (discussed in Appendix D).

TABLE 5.13

SUMMARY OF HYPOTHESIS TESTS

UNIT BASIS OF ANALYSIS (n=80)

HYPOTHESIS	RELATIONSHIP	CONCLUSION
1a	R vs. D and Number of Task Exceptions	S
1b	R vs. D and Degree of Analyzability	NS
1c*	R vs. D and Non-routine Technology	NS
2a	R vs. D and Complexity/Dynamism of Environment	NS
2b	R vs. D and Predictability/Controllability of Environment	NS
2c*	R vs. D and Environmental Uncertainty	NS
3a	R vs. D and Dependence on Other Units	S
3b	R vs. D and Other Units Dependence	S
3c*	R vs. D and Inter-unit Dependence	S
4a	Number of Task Exceptions and Information Source Requirements	NS
4b	Degree of Task Analyzability and Information Source Requirements	NS
4c*	Non-routine technology and Information Source Requirements	NS
5a	Complexity/Dynamism and Information Source Requirements	S
5b	Predictability/Controllability and Information Source Requirements	PS**
5c*	Environmental Uncertainty and Information Source Requirements	NS
6a	Dependence on Other Units and Information Source Requirements	S
6b	Other Units Dependence and Information Source Requirements	S
6c*	Inter-unit Dependence and Information Source Requirements	S

TABLE 5.13 (cont'd)

7a	Centralization and Accessibility/Quality of Information Sources	S
7b	Formalization and Accessibility/Quality of Information Sources	NS
7c	Participation in Decision Making and Accessibility/Quality of Information Sources	S
7d	Unit structure and accessibility/Quality of Information Sources	S
8	Inter-unit coordination and accessibility/Quality of Information Sources	NS
9	Degree of Difference and Unit Effectiveness	PS

S = Hypothesis Supported
PS = Hypothesis Partially Supported
NS = Hypothesis Not Supported

* Operationalized Variable of the Tushman and Nadler Information Processing Model (Figure 4.1)

** Opposite direction

CHAPTER 6

PATH ANALYSIS OF THE TUSHMAN/NADLER MODEL

6.1 Introduction

In exploring the variable inter-relationships, researchers
initially support their proposed causal relationships by drawing from
previous knowledge published within the literature. By
operationalizing the conceptual model, one can determine if the
theoretical variable inter-relationships are statistically supported.
However, exogenous variables may affect the relationships between the
model variables, particularly in sociological research. High
correlation coefficients (r's) of .7 or .8 are seldom attained.
Kerlinger (1973) maintains that r's of .1, .2, or .3 are acceptable,
provided they are statistically significant, to allow for inferences
to be made.

This study operationalized the Tushman and Nadler (1978) model of
organizational design and effectiveness through the use of previous
research studies and conceptualizations. The proposed causal
relationships set forth by the Tushman/Nadler model were tested with
the statistical technique of path analysis to assess the statistical
validity of the model within this field setting (see Appendix D for a
brief discussion of the path analysis technique).

6.2 Variable Level Path Analysis

The basic path analytic model examined is shown in Figure 6.1. An examination of the frequency distribution of the items as well as residual analysis performed on regressions used in the hypothesis testing did not provide any evidence to indicate that the data was inappropriate for use in regression analysis, an essential part of the path analysis technique.

The first phase of the path analysis technique is the *determination of the completeness* of the relevant relationships proposed by the model by calculating the path coefficients from the residual variables associated with their respective X_i's. Path coefficients are estimated by first deriving the residual (latent) variable's coefficient, the $\sqrt{1 - R^2}$, where the multiple R is determined from the regression equation where X_i is the dependent variable and all causally prior variables are used as independent (predictor) variables. Table 6.1 shows the regression equations calculated from the empirical data for the model shown in Figure 6.1.

FIGURE C.1

PATH ANALYTIC VERSION OF HUSEMAN SATTER INFORMATION FLOW COLL MODEL
OF ORGANIZATIONAL DESIGN AND THE LINKS — J.A.E. COSTS
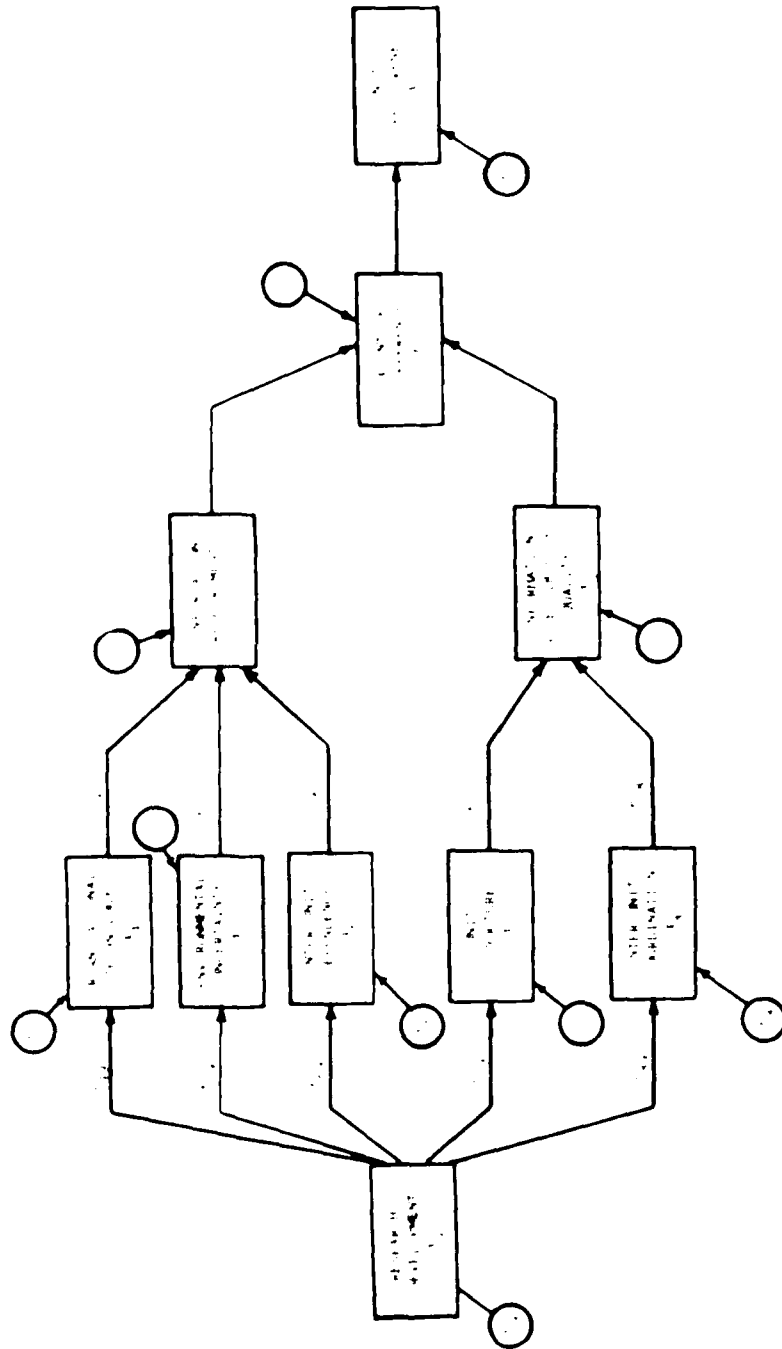
Table 6.1

Calculated Regression Equations for Model in Figure 6.1

Dependent Variable	Regression Equation	R^2 Value	Multiple R
Research/Development	$X_9 = $ (Initiating Variable*)	-	-
Inter Coordination	$X_8 = .52303X_9$	.273	.523
Unit Structure	$X_7 = .16052X_9$	.026	.161
Inter-Unit Dependence	$X_6 = .48225X_9$	.233	.482
Environmental Uncertainty	$X_5 = .12545X_9$	.016	.125
Organizational Technology	$X_4 = .17309X_9$	.030	.173
Information Accessability/ Quality	$X_3 = .24959X_7 - .03731X_8$	.062	.249
Information Requirements	$X_2 = .06242X_4 + .10122X_5 + .07520X_6$	.018	.132
Degree of Fit	$X_1 = .89533X_2 - .63233X_3$	1.000	1.000
Unit Effectiveness	$X_0 = -.02802X_1$	.001	.028

*Dummy Variable

A path coefficient is equivalent to a zero-order correlation whenever a variable is conceptualized as being dependent on a single cause (independent variable) and a residual. The same principle holds when a variable is conceived to be dependent on more than one cause, provided the causes are independent (Kerlinger and Pedhazur, 1973).

Figure 6.2 shows the model with the latent variable coefficients. Note that the latent variables E_7, E_5, E_4, E_3, E_2 and E_0 account for greater than 95 percent of the variation as unexplained by their respective X_i's, and F_6 and E_8 identify approximately 88 and 85 percent, respectively, for their X_i's. E_1 explains 0 percent of the variation for X_1, the degree of "difference" variable (this is to be expected since X_1 is simply the difference between x_2 and x_3). That is, the model explains less than 5 percent of the variation in these variables: technology, environmental uncertainty, unit structure, information source requirements, accessibility/quality of information, and unit effectiveness. About 12 and 15 percent of the variance in inter-unit dependence and coordination is explained by the model, respectively. The residual E_9 is assumed to account for all variation in the variable X_9 (Research or Development) because the only influences acting upon X_9 in the model are extraneous ones.

FIGURE ...

TOSERVX SADDLER CAUSAL MODEL FOR R&D IN LR'S
WITH PATH ANALYSIS RESIDUAL VALUES IDENTIFIED
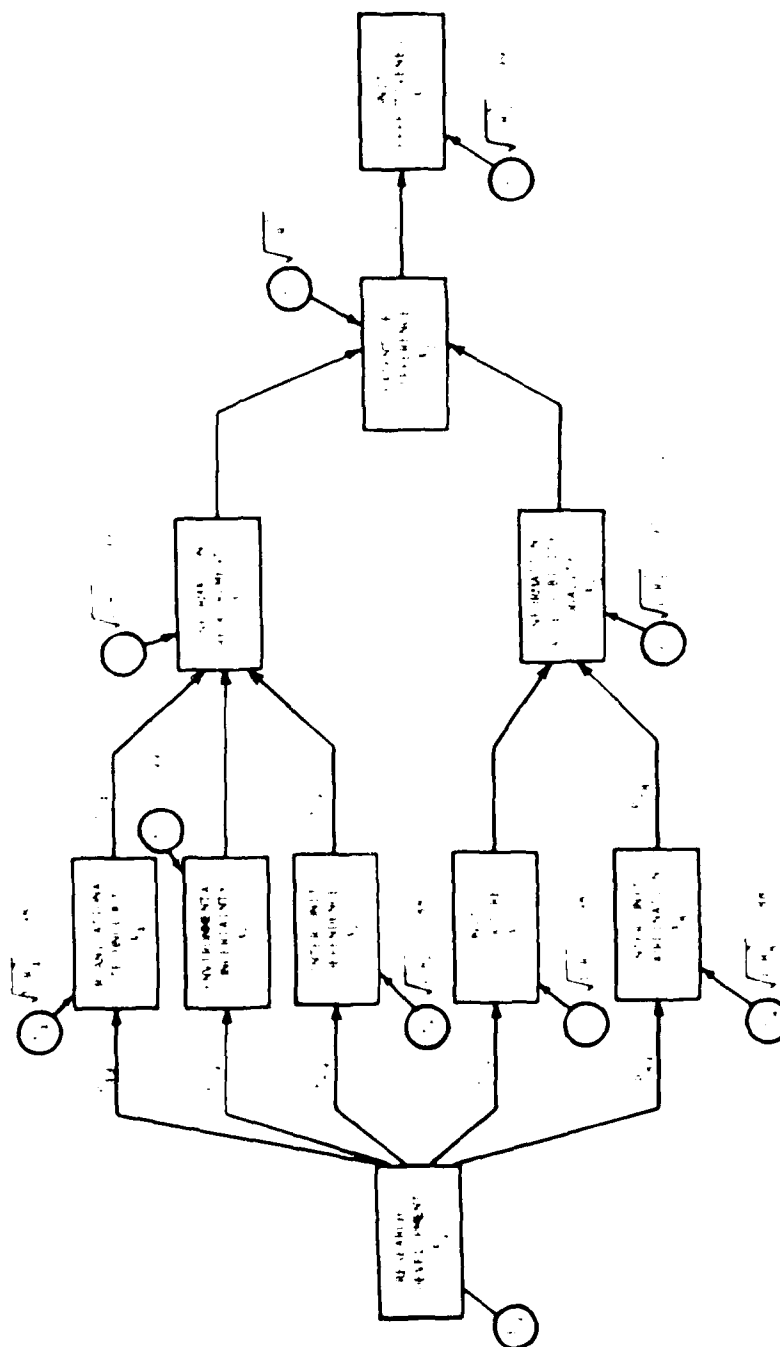
The second phase of the path analysis technique identifies the effects of any prior causal variable (X_j) on the variable under consideration (X_i) by calculating its effect coefficient, C_{ij}. Table 6.2 identifies how effect coefficients are calculated by decomposing the bivariate covariance into causal and non-causal components. The effect coefficient measures the accompanying changes in i given a unit change in X_j while controlling for extraneous ca' For the model in Figure 6.1, the path coefficients, P_{ij}, ' al their respective effect coefficients, C_{ij}, since only one direct path is proposed between each set of variables. That is, no indirect causal relationships are conceived in the Tushman/Nadler model.

Figure 6.3 presents the model under consideration with the calculated path coefficients. The path analysis indicated only three non-trival relationships where the effect of one variable on another can be identified as different from zero. The variable X_9 (R&D), has an effect on X_6 and X_8 (inter-unit dependence and coordination) since their path (beta) coefficients, .48 and .52, respectively, are much greater than their standard errors (.12 and .09, respectively). By the same rationale, the variable X_7 (unit structure) has an effect on X_3 (accessability/quality of information), where the standard error (.07) is smaller than the path (beta) coefficient (-.25).

Table 6.2

Decomposition Table for Path Analysis of Model Shown in Figure 6.1

Bivariate Relationship	Total Covariation (A)	Causal Direct (B)	Causal Indirect (C)	Causal Total: C_{ij} (D = B + C)	Non Causal (E = A - D)
$X_8 X_9$	r_{89} = .5230	r_{89} = .5230***	None	r_{89} = .5230	None
$X_7 X_9$	r_{79} = .1605	r_{79} = .1605	None	r_{79} = .1605	None
$X_6 X_9$	r_{69} = .4823	r_{69} = .4823***	None	r_{69} = .4823	None
$X_5 X_9$	r_{59} = .1254	r_{59} = .1254	None	r_{59} = .1254	None
$X_4 X_9$	r_{49} = .1731	r_{49} = .1731	None	r_{49} = .1731	None
$X_2 X_4$	r_{24} = -.0431	r_{24} = .0431	None	r_{24} = .0624	None
$X_2 X_5$	r_{25} = .0893	r_{25} = .0893	None	r_{25} = .0893	None
$X_2 X_6$	r_{26} = .0762	r_{26} = .0762	None	r_{26} = .0762	None
$X_3 X_7$	r_{37} = .2460	r_{37} = .2460	None	r_{37} = .2460	None
$X_3 X_8$	r_{38} = .0131	r_{38} = .0131	None	r_{38} = .0131	None
$X_1 X_2$	r_{12} = .7828	r_{12} = .7828***	None	r_{12} = .7828	None
$X_1 X_3$	r_{13} = .4730	r_{13} = -.4730***	None	r_{13} = -.4730	None
$X_0 X_1$	r_{01} = .0280	r_{01} = .0280	None	r_{01} = .0280	None

* $p < .05$
** $p < .01$
*** $p < .001$

FIGURE 6.5

CUSHMAN-SADLER CAUSAL MODEL FOR R&D UNITS
WITH PATH COEFFICIENTS BY VARIABLE
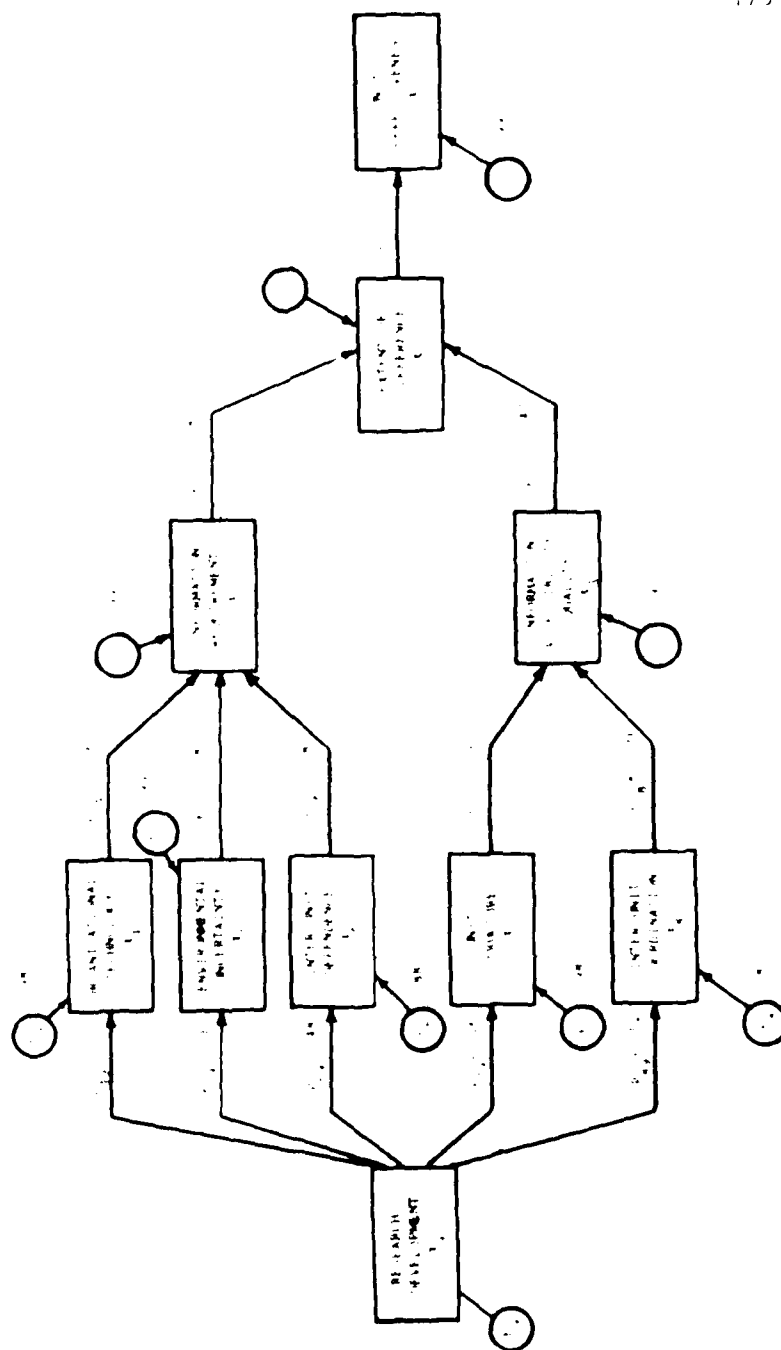
The results of this analysis indicated minimal support for the overall model as conceptualized in Figure 6.1. However, the effect of the R&D variable seemed to warrant further analysis. That is, to provide additional insight into the variable inter-relationships, separate path analyses were performed for the Research units (n = 42) and the Development units (n = 38).

The results of the path analyses are presented in Figure 6.4 and Tables 6.3 and 6.4 for research units, and in Tables 6.5 and 6.6 and Figure 6.5 for development units.

A path analysis of the Tushman/Nadler model shown in Figure 6.4 using only the 41 research units, indicated significant relationships for only the relationship between unit structure and information source accessibility/quality. The path analysis for development units (n=38) shown in Figure 6.5 did not yield any significant path coefficients. However, a comparison of the two path analyses (reference Figures 6.4 and 6.5) indicates that several of the path coefficients, although not statistically significant, were in opposite directions. For instance, in the development units, positive path coefficients were found between contextual variables and information source requirements (as expected); in the research units, a negative relationship was found. Similarly, and perhaps more importantly, was

that this same situation was found for the relationship between the "degree of difference" variable and unit effectiveness. That is, development units had a negative (although insignificant) relationship between "degree of difference" and unit effectiveness, as hypothesized. However, research units had a positive (although insignificant) relationship between the two variables.

FIGURE 6.1

PATH ANALYTIC VERSION OF TUSHMAN-NADLER MODEL

(RESEARCH UNITS)

Table 6.3

Calculated Regression Equations for Model in Figure 6.4 (Research Units)

Dependent Variable	Regression Equation	R^2Value	Multiple R
Information Accessability/ Quality	$X_3 = .42181X_7 + .17935X_8$	.212	.461
Information Requirements	$X_2 = .14786X_4 + .04979X_5 + .08602X_6$	.033	.181
Degree of Fit	$X_1 = .92297X_2 \quad .79904X_3$	1.000	1.000
Unit Effectiveness	$X_0 = .1611X_1$	.026	.160

X_4 = Organizational Technology
X_5 = Environmental Uncertainty
X_6 = Inter-Unit Dependence
X_7 = Unit Structure
X_8 = Inter-Unit Coordination

Table 6.4

Decomposition Table for Path Analysis of Model
Shown in Figure 6.4 (Research Units)

Bivariate Relationship	Total Covariation (A)	Causal			Non Causal (E = A - D)
		Direct (B)	Indirect (C)	Total: C_{ij} (D = B + C)	
X_3X_8	.1856	.1856	None	.1856	None
X_3X_7	.4245**	.4245	None	.4245	None
X_2X_6	.1006	.1006	None	.1006	None
X_2X_5	.0360	.0360	None	.0360	None
X_2X_4	-.1515	-.1515	None	-.1515	None
X_1X_3	-.4922	-.4922***	None	-.4922	None
X_1X_2	.6573	.6573***	None	.6573	None
X_0X_1	.1611	.1611	None	.1611	None

* $p < .05$
** $p < .01$
*** $p < .001$

FIGURE 6.3

PATH ANALYTIC VERSION OF TUSHMAN MODEL

(DEVELOPMENT UNITS)
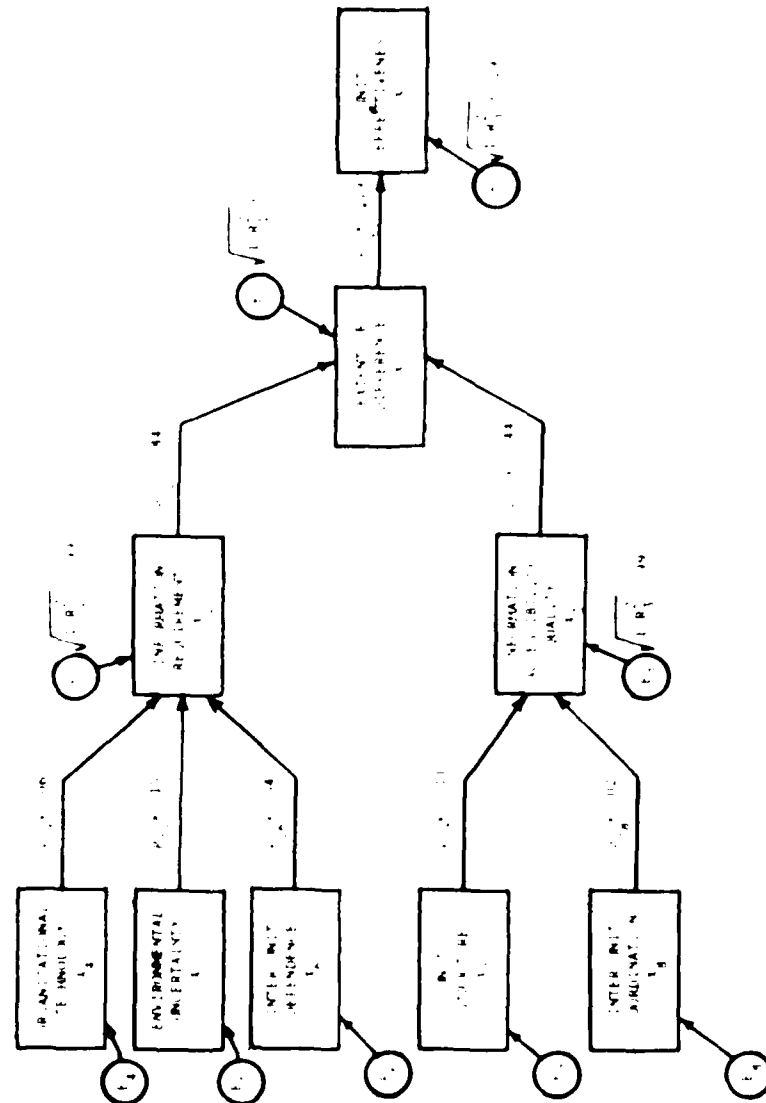
Table 6.5

Calculated Regression Equations for Model in Figure 6.5 (Development Units)

Dependent Variable	Regression Equation	R^2 Value	Multiple R
Information Accessability/ Quality	$X_3 = .1104/X_7 + .02258X_8$	.013	.113
Information Requirement	$X_2 = .01179X_4 + .13988X_9 + .01424X_6$	.022	.150
Degree of Fit	$X_1 = .90172X_2 - .54407X_3$	1.000	1.000
Unit Effectiveness	$X_0 = .18510X_1$	.046	.215

X_4 = Organizational Technology
X_5 = Environmental Uncertainty
X_6 = Inter-Unit Dependence
X_7 = Unit Structure
X_8 = Inter-Unit Coordination

Table 6.6

Decomposition Table for Path Analysis of Model Shown in Figure 6.5 (Development Units)

Bivariate Relationship	Total Covariation (A)	Direct (B)	Causal Indirect (C)	Total: C_{ij} (D = B + C)	Non Causal (t = A - D)
$X_3 X_8$	.0245	.0245	None	.0245	None
$X_3 X_7$	.1109	-.1109	None	.1109	None
$X_2 X_6$	.0375	.03775	None	.0375	None
$X_2 X_5$	.1454	.1454	None	.1454	None
$X_2 X_4$	.0573	.0573	None	.0573	None
$X_1 X_3$	.4438***	.4438	None	.4438	None
$X_1 X_2$	.8412***	.8412	None	.8412	None
$X_0 X_1$	.2152	-.1850	None	-.1850	None

* $p < .05$
** $p < .01$
*** $p < .001$

6.3 Dimensional Level Path Analysis

To examine these potential differences between research and development units, path analyses were performed at the dimensional level. Figure 6.6 represents the information processing model at the dimensional level of analysis. For simplification, the path arrows have been excluded, although the same causal relationships are assumed to exist as in Figures 6.4 and 6.5. Since the dimensional model shown in Figure 6.6 is proposed as having independent causal relationships, the path coefficients are equal to the zero-order correlations between variable dimensions, as previously discussed. To simplify presentation of the analysis, the path coefficients between variable dimensions are segmented by sections of the dimensional model. These sections correspond to: the effect of the organizational variable dimensions on the accessiblity/ quality of information from the four sources (supervisor, unit members, other organizational members, and external to organization) the effect of the contextual variables dimensions on the information required from each of the four information sources, and the "degree of fit" between the accessibilty/quality of an information source and the corresponding information source requirements and unit effectiveness. Table 6.7 and Figure 6.7 present the results of the path analysis on the dimensional

2
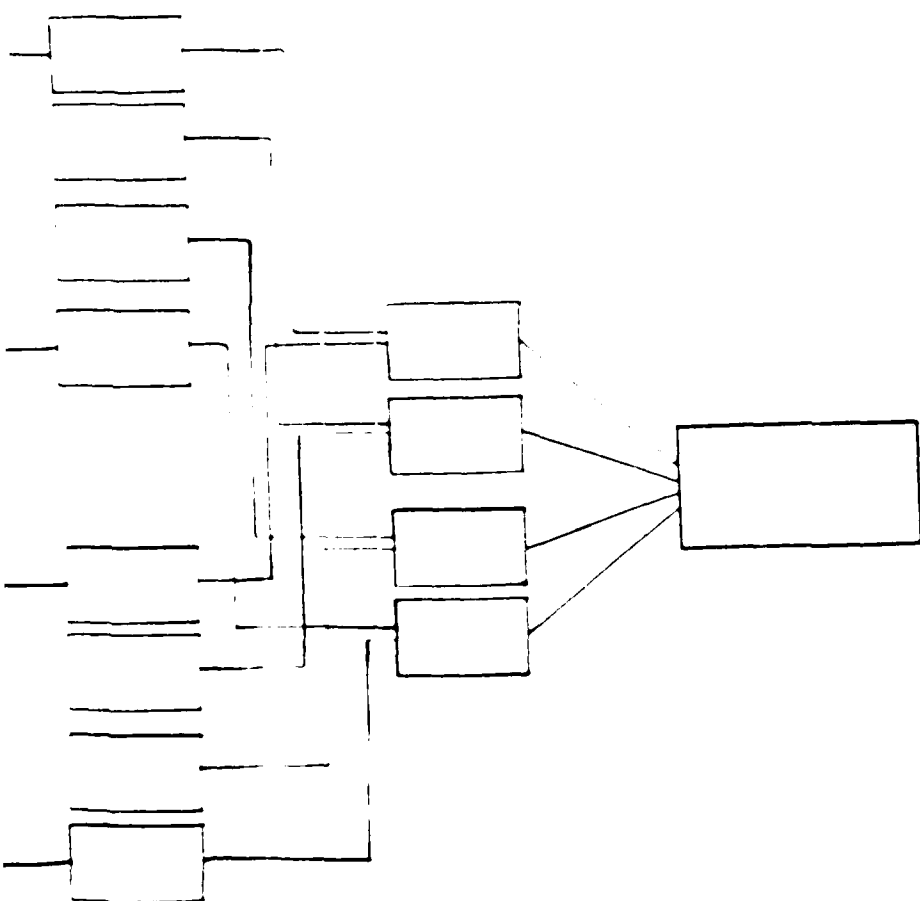
level information processing model for research units. Table 6.8 and Figure 6.8 present the results of the path analysis on the dimensional level information processing model for development units.

Comparison of the two analyses results in the identification of significant differences between the two groups with regard to the impact of the contextual dimensions on information requirements. For instance, in research units, as the number of task exceptions (a dimension of technology) increased, a significant decrease was found in information required from the unit manager/supervisor (p < .05). However, in development units, an increase in the number of task exceptions resulted in an increase in extra-organizational information requirements. The impact of the complexity/dynamism dimension of environmental uncertainty also had different implications for information source requirements. In research units, high environmental complexity/dynamism resulted in significantly greater extra-organizational information requirements (p < .01). In development units, increases in environmental complexity resulted in significant increases in intra-unit information requirement (unit manager, p < .001 and unit members, p < .05).

For development groups the two dimensions of inter-unit dependence (i.e., degree of dependence on other units and other units dependence

on your unit) resulted in opposite effects for information source requirements. That is, dependence on other units resulted in greater information required of the unit manager ($p < .05$) and extra-organizational ($p < .001$) information requirements. However, the greater other units were dependent, the less information was required of the unit manager (significant at the .001 level).

No significant relationship was found between the "degree of difference" dimensions and unit effectiveness. However, a significant, *negative relationship* ($p < .05$) was found for development units between the degree of difference in fit and unit effectiveness. Tables 6.7 and 6.8 provide the summarized results of the path analyses performed for research units and development units, respectively.

Figures 6.7 *and* 6.8 illustrate the significant path coefficients found for research units and development units, respectively, in terms of the dimensional level information processing model.

2

Table 6.1

Path Coefficients for Dimensional Model Shown in Figure 6.1

Research Units

Effect of Organizational Variables on Accessability/Quality of Information

X_i	X_j	Bivariate Relationship	Path Coefficient $P_{ij} - C_{ij}$
Centralization (X_{71})	Accessability/Quality of Information from Manager (X_{31})	$X_{71}X_{31}$	.3158
Centralization (X_{71})	Accessability/Quality of Information from Group Members (X_{32})	$X_{71}X_{32}$	.1260
Centralization (X_{71})	Accessability/Quality of Information from Others in Organization (X_{33})	$X_{71}X_{33}$	.0132
Centralization (X_{71})	Accessability/Quality of Information from Outside of Organization (X_{34})	$X_{71}X_{34}$	.1922
Formalization (X_{72})	Accessability/Quality of Information from Manager (X_{31})	$X_{72}X_{31}$	.2224
Formalization (X_{72})	Accessability/Quality of Information from Group Members (X_{32})	$X_{72}X_{32}$	.1403
Formalization (X_{72})	Accessability/Quality of Information from Others in Organization (X_{33})	$X_{72}X_{33}$	.0511
Formalization (X_{72})	Accessability/Quality of Information from Outside of Organization (X_{34})	$X_{72}X_{34}$	.0260
Participation in Decision Making (X_{73})	Accessability/Quality of Information from Manager (X_{31})	$X_{73}X_{31}$	.4615**
Participation in Decision Making (X_{73})	Accessability/Quality of Information from Group Members (X_{32})	$X_{73}X_{32}$	.6509***
Participation in Decision Making (X_{73})	Accessability/Quality of Information from Others in Organization (X_{33})	$X_{73}X_{33}$	.3511
Participation in Decision Making (X_{73})	Accessability/Quality of Information from Outside of Organization (X_{34})	$X_{73}X_{34}$	.4821*

Table 6 / (cont'd)

Path Coefficients for Dimensional
Model Shown in Figure 6 /

Research Units

Effect of Organizational Variables on Accessability/Quality
of Information

X_i	X_j	Bivariate Relationship	Path Coefficient $P_{ij} = C_{ij}$
Inter-Unit Coordination (X_{81})	Accessability/Quality of Information from Manager (X_{31})	$X_{81} X_{31}$	.1052
Inter-Unit Coordination (X_{81})	Accessability/Quality of Information from Group Members (X_{32})	$X_{81} X_{32}$	.1457
Inter-Unit Coordination (X_{81})	Accessability/Quality of Information from Others in Organization (X_{33})	$X_{81} X_{33}$	.1162
Inter-Unit Coordination (X_{81})	Accessability/Quality of Information from Outside of Organization (X_{34})	$X_{81} X_{34}$	.0156

* $p < .05$
** $p < .01$
*** $p < .001$

Table 6.7 (cont'd)

Path Coefficients for Dimensional
Model Shown in Figure 6.7

<u>Research Units</u>

Effect of Contextual Variables on Information Requirements

X_i	X_j	Bivariate Relationship	Path Coefficient $P_{ij} - C_{ij}$
Task Exceptions(X_{41})	Information Required from Manager(X_{21})	X_{41},X_{21}	.0860
Task Exceptions(X_{41})	Information Required from Group Members(X_{22})	X_{41},X_{22}	.3410
Task Exceptions(X_{41})	Information Required from Others in Organization(X_{23})	X_{41},X_{23}	.0969
Task Exceptions(X_{41})	Information Required from Outside of Organization(X_{24})	X_{41},X_{24}	.2331
Task Unanalyzability(X_{42})	Information Required from Manager(X_{21})	X_{42},X_{21}	.4766*
Task Unanalyzability(X_{42})	Information Required from Group Members(X_{22})	X_{42},X_{22}	.3029
Task Unanalyzability(X_{42})	Information Required from Others in Organization(X_{23})	X_{42},X_{23}	.0736
Task Unanalyzability(X_{42})	Information Required from Outside of Organization(X_{24})	X_{42},X_{24}	.0860
Complex/Dynamic(X_{51})	Information Required from Manager(X_{21})	X_{51},X_{21}	.0953
Complex/Dynamic(X_{51})	Information Required from Group Members(X_{22})	X_{51},X_{22}	.2037
Complex/Dynamic(X_{51})	Information Required from Others in Organization(X_{23})	X_{51},X_{23}	.0629
Complex/Dynamic(X_{51})	Information Required from Outside of Organization(X_{24})	X_{51},X_{24}	.4811**
Unpredictability of Environment (X_{52})	Information Required from Manager(X_{21})	X_{52},X_{21}	.1118
Unpredictability of Environment (X_{52})	Information Required from Group Members(X_{22})	X_{52},X_{22}	.1172
Unpredictability of Environment (X_{52})	Information Required from Others in Organization(X_{23})	X_{52},X_{23}	.0911
Unpredictability of Environment (X_{52})	Information Required from Outside of Organization(X_{24})	X_{52},X_{24}	.4638**

Table 6 / (cont'd)

Path Coefficients for Dimensional
Model Shown in Figure 6 /

Research Units

Effect of Contextual Variables on Information Requirements

X_i	X_j	Bivariate Relationship	Path Coefficient $P_{ij} - C_{ij}$
Dependence of Other Units(X_{61})	Information Required from Manager(X_{21})	$X_{61}X_{21}$	.1841
Dependence of Other Units(X_{61})	Information Required from Group Members(X_{22})	$X_{61}X_{22}$	.0854
Dependence of Other Units(X_{61})	Information Required from Others in Organization(X_{23})	$X_{61}X_{23}$	.1093
Dependence of Other Units(X_{61})	Information Required from Outside of Organization(X_{24})	$X_{61}X_{24}$	.2964*
Other Unit Dependent(X_{62})	Information Required from Manager(X_{21})	$X_{62}X_{21}$	.0420
Other Unit Dependent(X_{62})	Information Required from Group Members(X_{22})	$X_{62}X_{22}$	.3384
Other Unit Dependent(X_{62})	Information Required from Others in Organization(X_{23})	$X_{62}X_{23}$	.2540
Other Unit Dependent(X_{62})	Information Required from Outside of Organization(X_{24})	$X_{62}X_{24}$	.0808

* $p < .05$
** $p < .01$
*** $p < .001$

Table 6.7 (cont'd)

Path Coefficients for Dimensional
Model Shown in Figure 6.7

Research Units

Effect of Degree of Difference Between Information Source Requirement and
and Information Source Accessibility/Quality and Unit Effectiveness Measures

X_i	X_j	Bivariate Relationship	Path Coefficient $P_{ij} - C_{ij}$
Degree of Difference between Information Required of and Accessibility/Quality of Information from ...			
Unit Supervisor/Manager (X_{11})	Unit Effectiveness (X_0)	$X_{11}X_0$	.0809
Unit Members (X_{12})	Unit Effectiveness (X_0)	$X_{12}X_0$	.0753
Others in Organization (X_{13})	Unit Effectiveness (X_0)	$X_{13}X_0$	.0688
Extra Organizational Sources (XX_{14})	Unit Effectiveness (X_0)	$X_{14}X_0$	.1815

* $p < .05$
** $p < .01$
*** $p < .001$

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2
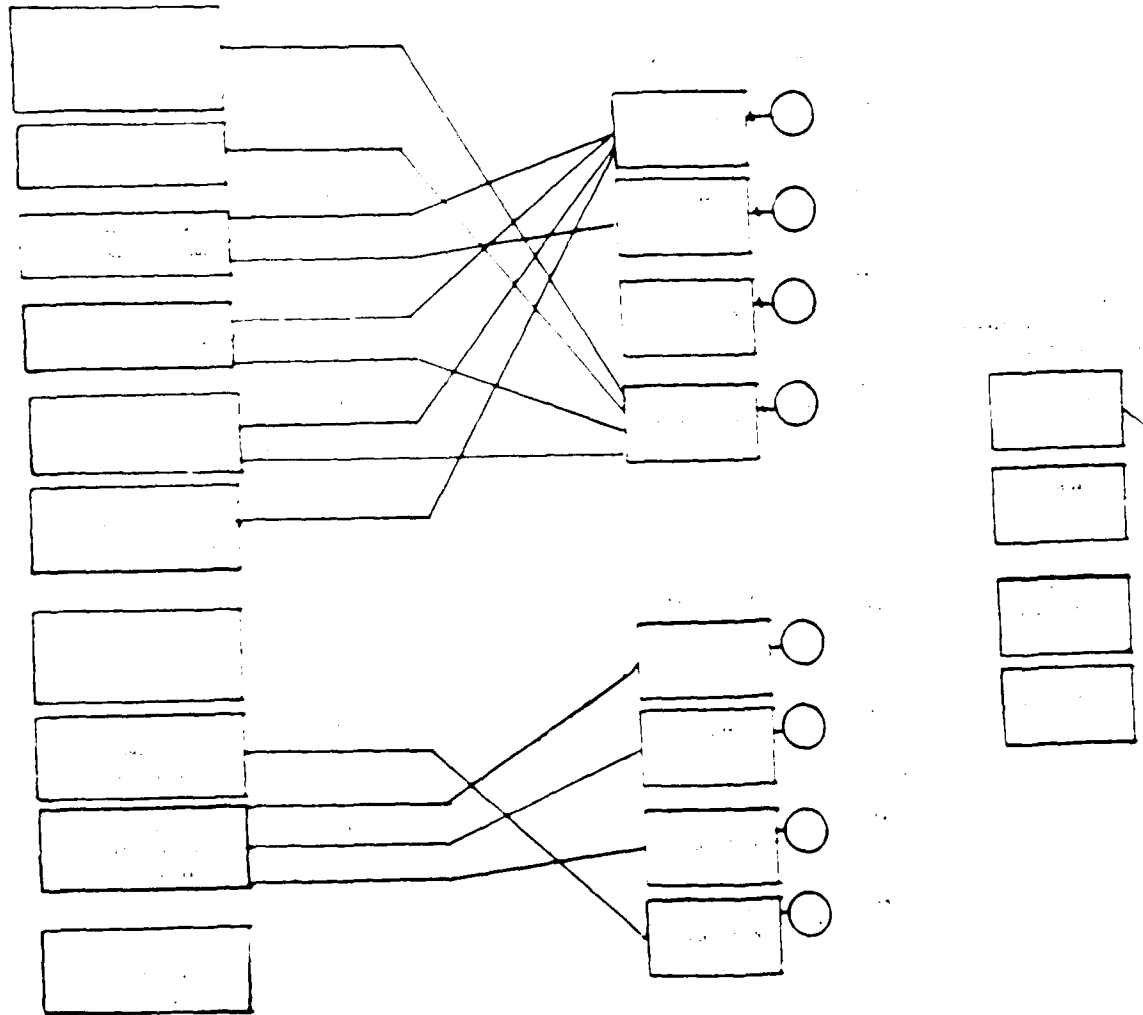
Table 6.8

Path Coefficients for Dimensional
Model Shown in Figure 6.8

Development Units

Effect of Organizational Variables on Accessability/Quality
of Information

X_i	X_j	Bivariate Relationship	Path Coefficient $P_{ij} - C_{ij}$
Centralization (X_{11})	Accessability/Quality of Information from Manager (X_{31})	$X_{11}X_{31}$	.0875
Centralization (X_{11})	Accessability/Quality of Information from Group Members (X_{32})	$X_{11}X_{32}$	.0453
Centralization (X_{11})	Accessability/Quality of Information from Others in Organization (X_{33})	$X_{11}X_{33}$	.2150
Centralization (X_{11})	Accessability/Quality of Information from Outside of Organization (X_{34})	$X_{11}X_{34}$	.1884
Formalization (X_{12})	Accessability/Quality of Information from Manager (X_{31})	$X_{12}X_{31}$	.1579
Formalization (X_{12})	Accessability/Quality of Information from Group Members (X_{32})	$X_{12}X_{32}$	.2128
Formalization (X_{12})	Accessability/Quality of Information from Others in Organization (X_{33})	$X_{12}X_{33}$	.2998
Formalization (X_{12})	Accessability/Quality of Information from Outside of Organization (X_{34})	$X_{12}X_{34}$	.4007*
Participation in Decision Making (X_{13})	Accessability/Quality of Information from Manager (X_{31})	$X_{13}X_{31}$	.3628*
Participation in Decision Making (X_{13})	Accessability/Quality of Information from Group Members (X_{32})	$X_{13}X_{32}$	.4322*
Participation in Decision Making (X_{13})	Accessability/Quality of Information from Others in Organization (X_{33})	$X_{13}X_{33}$	.3592*
Participation in Decision Making (X_{13})	Accessability/Quality of Information from Outside of Organization (X_{34})	$X_{13}X_{34}$	.2190

Table 6 8 ((cont'd)

Path Coefficients for Dimensional
Model Shown in Figure 6 8

Development Units

Effect of Organizational Variables on Accessability/Quality
of Information

X_i		Bivariate Relationship	Path Coefficient $P_{ij} = C_{ij}$
Inter Unit Coordination (X_{81})	Accessability/Quality of Information from Manager (X_{31})	$X_{81}X_{31}$	.0948
Inter-Unit Coordination (X_{81})	Accessability/Quality of Information from Group Members (X_{32})	$X_{81}X_{32}$	.1209
Inter-Unit Coordination (X_{81})	Accessability/Quality of Information from Others in Organization (X_{33})	$X_{81}X_{33}$	.1600
Inter-Unit Coordination (X_{81})	Accessability/Quality of Information from Outside of Organization (X_{34})	$X_{81}X_{34}$	.0439

* $p < .05$
** $p < .01$
*** $p < .001$

Table 6.8 (cont'd)

Path Coefficients for Dimensional
Model Shown in Figure 6.8

Development Units

Effect of Contextual Variables on Information Requirements

X_i	X_j	Bivariate Relationship	Path Coefficient $P_{ij} - C_{ij}$
Task Exceptions(X_{41})	Information Required from Manager(X_{21})	X_{41}, X_{21}	.2641
Task Exceptions(X_{41})	Information Required from Group Members(X_{22})	X_{41}, X_{22}	.0006
Task Exceptions(X_{41})	Information Required from Others in Organization(X_{23})	X_{41}, X_{23}	.2181
Task Exceptions(X_{41})	Information Required from Outside of Organization(X_{24})	X_{41}, X_{24}	.5141**
Task Unanalyzability(X_{42})	Information Required from Manager(X_{21})	X_{42}, X_{21}	.2321
Task Unanalyzability(X_{42})	Information Required from Group Members(X_{22})	X_{42}, X_{22}	.2384*
Task Unanalyzability(X_{42})	Information Required from Others in Organization(X_{23})	X_{42}, X_{23}	.1177
Task Unanalyzability(X_{42})	Information Required from Outside of Organization(X_{24})	X_{42}, X_{24}	.5266**
Complex/Dynamic(X_{51})	Information Required from Manager(X_{21})	X_{51}, X_{21}	.4791***
Complex/Dynamic(X_{51})	Information Required from Group Members(X_{22})	X_{51}, X_{22}	.3851*
Complex/Dynamic(X_{51})	Information Required from Others in Organization(X_{23})	X_{51}, X_{23}	.2190
Complex/Dynamic(X_{51})	Information Required from Outside of Organization(X_{24})	X_{51}, X_{24}	.2626
Unpredictability of Environment (X_{52})	Information Required from Manager(X_{21})	X_{52}, X_{21}	.3137*
Unpredictability of Environment (X_{52})	Information Required from Group Members(X_{22})	X_{52}, X_{22}	.0525
Unpredictability of Environment (X_{52})	Information Required from Others in Organization(X_{23})	X_{52}, X_{23}	.0752
Unpredictability of Environment (X_{52})	Information Required from Outside of Organization(X_{24})	X_{52}, X_{24}	.2871*

Table 6 8 (cont'd)
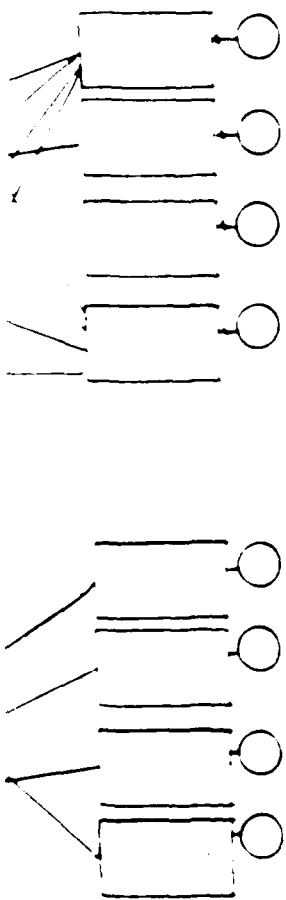
Path Coefficients for Dimensional
Model Shown in Figure 6 8

Development Units

Effect of Contextual Variables on Accessability/Quality
of Information

X_i	X_j	Bivariate Relationship	Path Coefficient $P_{ij} = C_{ij}$
Dependence of Other Units(X_{61})	Information Required from Manager(X_{21})	$X_{61} X_{21}$	.3403
Dependence of Other Units(X_{61})	Information Required from Group Members(X_{22})	$X_{61} X_{22}$	.0967
Dependence of Other Units(X_{61})	Information Required from Others in Organization(X_{23})	$X_{61} X_{23}$	.2844
Dependence of Other Units(X_{61})	Information Required from Outside of Organization(X_{24})	$X_{61} X_{24}$	.5623***
Other Unit Dependent(X_{62})	Information Required from Manager(X_{21})	$X_{62} X_{21}$	.4886***
Other Unit Dependent(X_{62})	Information Required from Group Members(X_{22})	$X_{62} X_{22}$	.1171
Other Unit Dependent(X_{62})	Information Required from Others in Organization(X_{23})	$X_{62} X_{23}$	.0103
Other Unit Dependent(X_{62})	Information Required from Outside of Organization(X_{24})	$X_{62} X_{24}$	.1894

* $p < .05$
** $p < .01$
*** $p < .001$

Table 6 8 ((ont'd)

Path Coefficients for Dimensional
Model Shown in Figure 6 8

Development Units

Effect of Degree of Difference Between Information Source Requirement and
and Information Source Accessibility/Quality and Unit Effectiveness Measures

X_i	X_j	Bivariate Relationship	Path Coefficient $P_{ij} - C_{ij}$
Degree of Difference between Information Required of and Accessibility/Quality of Information from ...			
Unit Supervisor/Manager (X_{11})	Unit Effectiveness (X_0)	$X_{11}X_0$	.3635*
Unit Members (X_{12})	Unit Effectiveness (X_0)	$X_{12}X_0$	.2152
Others in Organization (X_{13})	Unit Effectiveness (X_0)	$X_{13}X_0$	.1623
Extra Organizational Sources (XX_{14})	Unit Effectiveness (X_0)	$X_{14}X_0$	.1382

* $p < .05$
** $p < .01$
*** $p < .001$

6.4 Summary of Path Analyses

The results of the path analyses performed at both the variable
and dimensional levels of analysis provided statistical support for
only some of the relationships proposed within the Tushman and
Nadler(1978) information processing model. A comparison between the
path analyses performed for research units and for development units
indicates several relationships where contextual dimensions had
different effects on information source requirements.

In particular, for research units (n = 42), four significant path
coefficients were found between contextual dimensions and information
source requirements. The statistically significant relationships for
the dimensional level path analysis are summarized below.

(1) Task unanalyzability was negatively related to information
     required from the unit manager.

(2) Complexity/dynamism of the external environment was
     positively related to information required from sources
     outside the laboratory.

(3) Unpredictability/uncontrollability of the external
     environment was negatively related to information required
     from sources outside of the laboratory.

(4) Inter-unit dependence was positively related to information
     required from sources outside of the laboratory.

For development units (n = 38), nine statistically significant path coefficients were identified between the contextual dimensions and information source requirements. Note that several of these relationships, summarized below, are different from those found in the research unit path analysis.

(1) The number of task exceptions was negatively related to information required from sources outside the product division.

(2) Task unanalyzability was positively related to information required from sources outside the product division.

(3) Complexity/dynamism of the external environment was positively related to information required from the unit manager and unit members.

(4) Unpredictability/controllability of the external environment was negatively related to information required from sources outside the product division and the unit manager.

(5) Dependence on other organizational units was positively related to information required from the unit manager and sources outside of the organization.

(6) Other units dependent was negatively related to information required from the unit manager.

Note also that a significant negative relationship existed between the "degree of difference" measure for the unit manager and unit effectiveness.

Overall, the results obtained from the path analyses at the dimensional level provide further evidence that differences exist in the underlying dynamics between research units and development units. The next chapter provides an alternative information processing formulation, and further examines and explains the relationships found within the data.

CHAPTER 7

AN ALTERNATIVE INFORMATION PROCESSING FORMULATION
FOR AIR FORCE R&D UNITS

7.1 Overview

The results of the analysis reported in the previous chapter suggest that the empirical data does not allow confirmation of the model as conceptualized by Tushman and Nadler (1978). The lack of supporting evidence for the Tushman/Nadler model may be a result of a restricted data range for many of the measured variables (see Figures 5.1, 5.2 and 5.3). Where variability did exist, however, such as in the inter unit dependence measure or unit structure, hypothesized relationships were supported. Overall, the data suggests that both research and development units are characterized as having non-routine technology, operating in an uncertain environment, and being relatively independent of other organizational units. Therefore, empirically, there appears to be little difference between the research and the development units with regard to the contextual variables. This may be due to the fact that in the Air Force Systems Command "research" is applied to specific, user-defined needs and is more "advanced development" oriented. Similarly, within AFSC, "development" is really systems engineering, and requires some advanced "systems research" or integration which in itself is "non-routine". Thus, the research and development units in AFSC are

closer together than, say, the "Central Research Laboratory" and "Product Development Unit" in a typical manufacturing company (e.g., 3M).

However, since the Tushman/Nadler information processing conceptualization did not adequately explain the correlations among the variables, an alternative formulation was developed based on the empirical relationships. The purpose of this chapter is to present and discuss this alternative formulation which offers insight into the variable inter-relationships identified within the data.

Path analysis, as discussed in the previous chapter and appendix D, is an important analytic technique for theory or model testing (Kerlinger and Pedhazur, 1973). Chapter 6 employed path analysis to assess relationships within the Tushman and Nadler (1978) information processing model of organizational design and effectiveness using data collected from USAF research and development organizations. Path analysis, used in this context, allows one to determine whether or not a pattern of correlations for a data set is consistent with a specific theoretic formulation. Chapter 6 used path analysis in the sense of theory testing; that is, an assessment of the Tushman/Nadler model. This chapter makes use of path analysis in the sense of theory modification or development, by proposing a revised model based on

relationships found within the data.

7.2 Alternative Formulation Based on Empirical Relationships

In the absence of empirical support for the Tushman and Nadler information processing model of organizational design and effectiveness, an alternative formulation was developed from the empirical relationships to attempt to assess which variables (if any) influence unit effectiveness. Figure 7.1, along with Tables 7.1 - 7.3 present the formulation in the path analytic format discussed in previous Chapters.[1] The causal pattern of relationships for this formulation were developed from a review of the zero-order correlation matrix (Table 7.4) and previous research results published in the organizational theory literature. This process allowed for the development of causal relationships having empirical significance as well as a theoretical basis.

The alternative formulation suggests that the technology (X_{40}) within a unit is an initiating variable influencing the structural dimensions of centralization (X_{71}), formalization (X_{72}) and

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[1] Note that the variable and dimension subscripts remain the same between models for consistency purposes.

2

Table 7-1
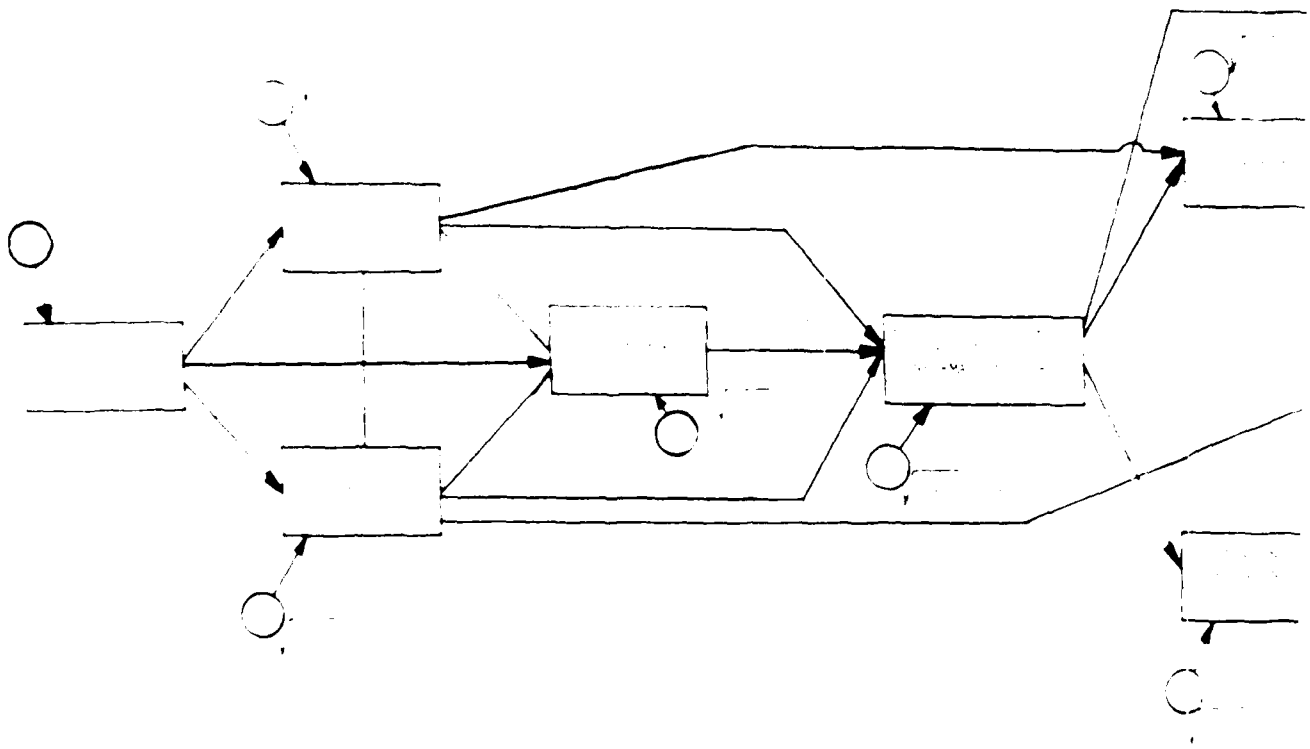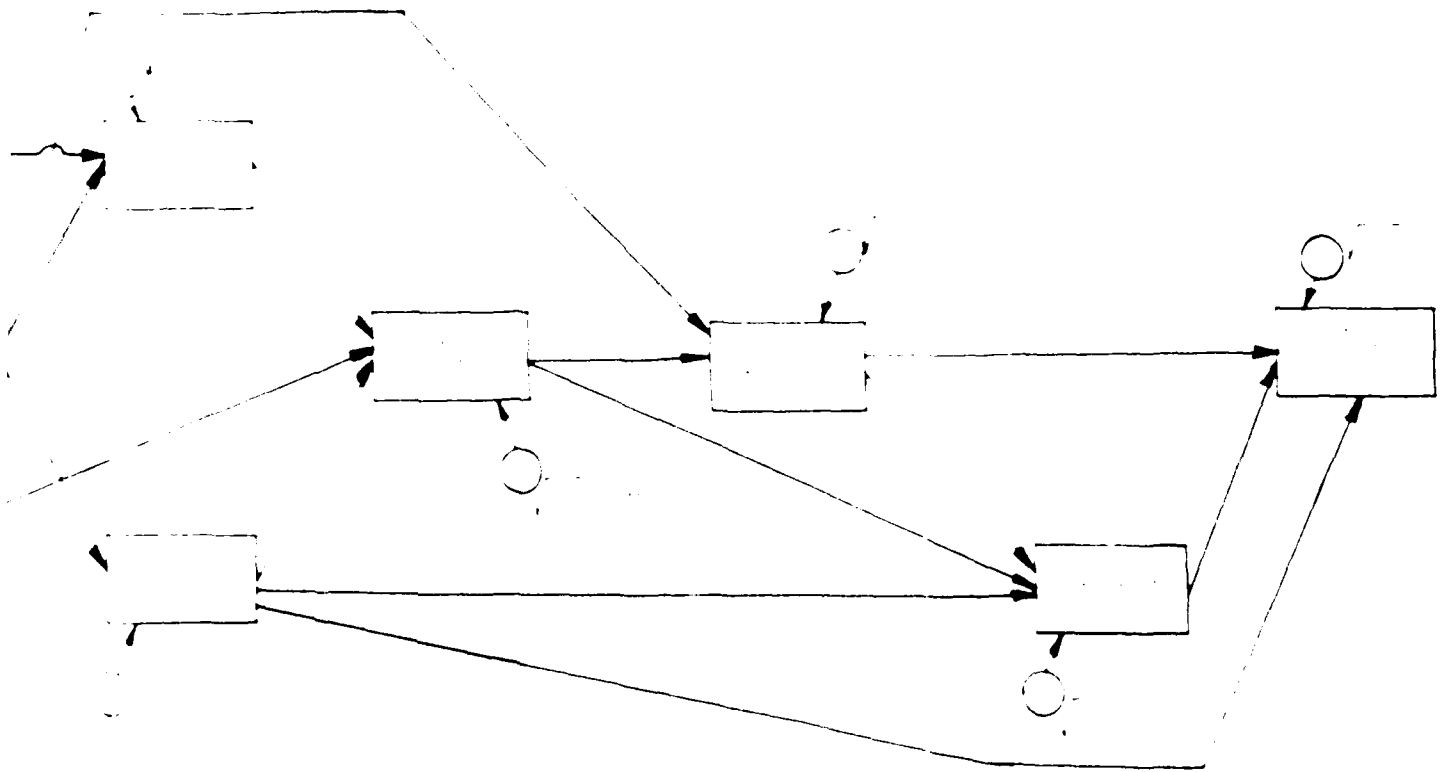
Calculated Regression Equations for Empirical Model in Figure 7-1

Dependent Variable	Regression Equation			R^2 value	Multiple R
Non Routine Technology	X_{40} (Initiating Variable)				
Unit Formalization	X_{12}	56719 X_{40}		322	567
Unit Centralization	X_{11}	30248 X_{40}		092	302
Participation in Decision Making	X_{13}	15943 X_{40}		025	159
Accessibility/Quality of Organizational Information Sources	X_{33}	03310 X_{11} + 14846 X_{12}	38121 X_{13}	170	413
Predictability of Environment	X_{52}	21656 X_{33} + 24550 X_{12}		119	345
Inter Unit Dependence	X_{60}	29502 X_{33}		087	295
Inter Unit Information Requirements	X_{23}	03916 X_{52} + 37038 X_{60}	22811 X_{11}	218	467
Degree of Difference between X_{23} and X_{33}	X_{13}	17855 X_{23}	62871 X_{33}	100	100
Inter Unit Coordination	X_{80}	00635 X_{13} + 33854 X_{60} +	15901 X_{23}	252	502
Unit Effectiveness	X_0	01638 X_{13}	32161 X_{80} 06991 X_{60}	131	361

Table 12

Decomposition Table for Path Analysis of Revised Model Shown in Figure 12

Bivariate Relationship	Total Covariation	Causal			Non Causal
		Direct	Indirect	Total $(_{,})$	
X_{71} X_{40}	.3075	.3075	None	.3075	None
X_{12} X_{40}	.5612	.5612	None	.5612	None
X_{13} X_{40}	.1594	.1594	None	.1594	None
X_{33} X_{71}	.1556	.0337	None	.0337	None
X_{33} X_{12}	.1113	.1113	None	.1113	None
X_{33} X_{73}	.3893	.3893	None	.3893	None
X_{52} X_{72}	.2696	.2455	.0322	.2777	.0081
X_{52} X_{72}	.2439	.2166	None	.2166	None
X_{52} X_{33}	.2950	.2950	None	.2950	None
X_{60} X_{33}	.4071	.4071	None	.4071	None
X_{23} X_{60}	.0449	.0449	None	.0449	None
X_{23} X_{52}	.2881	.2287	.0034	.2253	.0628
X_{23} X_{71}	.3003	.0063	None	.0063	.2940
X_{80} X_{13}	.3968	.2639	.0049	.2589	.1378
X_{80} X_{23}	.4427	.3385	.0977	.4362	.0065
X_{80} X_{60}	.1275	.0164	.0020	.0184	.1041
X_{0} X_{13}	.2090	.0700	.1390	.2090	None
X_{0} X_{60}					
X_{0} X_{80}	.3544	.3216	None	.3216	.0328

Table 7.3

T Ratio Tests for Statistical Significance of Revised Model Path Coefficients

H_0: $P_{i,j} = 0$ H_1: $P_{i,j} \neq 0$ $\alpha = .05$ level

Bivariate Relationship	H_0	Standardized Beta	T Ratio	T Significance	Conclusion
X71 X40	$P_{71,40} = 0$	.3025	2.80	.006	Reject H_0
X72 X40	$P_{72,40} = 0$	.5677	6.08	.001	Reject H_0
X73 X40	$P_{73,40} = 0$	.1594	1.43	.158	Fail to Reject H_0
X33 X71	$P_{33,71} = 0$	.0337	.25	.807	Fail to Reject H_0
X33 X72	$P_{33,72} = 0$	.1485	1.24	.218	Fail to Reject H_0
X33 X73	$P_{33,73} = 0$	.3812	3.10	.003	Reject H_0
X52 X72	$P_{52,72} = 0$	.2455	2.28	.025	Reject H_0
X52 X33	$P_{52,33} = 0$	.2166	2.01	.047	Reject H_0
X60 X33	$P_{60,33} = 0$	.2950	2.73	.008	Reject H_0
X23 X60	$P_{23,60} = 0$	.3704	3.61	.001	Reject H_0
X23 X52	$P_{23,52} = 0$	.0392	.39	.700	Fail to Reject H_0
X23 X71	$P_{23,71} = 0$	.2281	2.23	.030	Reject H_0
X13 X33	$P_{13,33} = 0$	.7186	10.96	.001	Reject H_0
X13 X23	$P_{13,23} = 0$	.6287	8.97	.001	Reject H_0
X80 X13	$P_{80,13} = 0$	.0063	.04	.970	Fail to Reject H_0
X80 X23	$P_{80,23} = 0$	.2639	1.67	.099	Fail to Reject H_0
X80 X60	$P_{80,60} = 0$	.3385	2.92	.004	Reject H_0
X0 X13	$P_{0,13} = 0$	.0164	.14	.890	Fail to Reject H_0
X0 X60	$P_{0,60} = 0$	.3216	2.11	.008	Reject H_0
X0 X80	$P_{0,80} = 0$	.0700	.56	.519	Fail to Reject H_0

Table 7.4

Zero order Correlation Matrix for Variables in Figure 7.1
(n = 80)

	X_{40}	X_{11}	X_{12}	X_{13}	X_{33}	X_{52}	X_{60}	X_{23}	X_{13}	X_{80}
Technology (X_{40})										
Centralization (X_{11})	30**									
Formalization (X_{12})	57***	45***								
Participation D M (X_{13})	16	49***	06							
Accessibility/Quality (X_{33})	07	16	11	39***						
Predictability (X_{52})	11	01	27**	13	24**					
Inter Unit Dependence (X_{60})	01	16	14	12	29**	01				
Information Requirement (X_{23})	07	28**	19	13	06	09	41***			
Degree of Difference (X_{13})	02	20*	12	12	40***	01	43***	64***		
Inter Unit Coordination (X_{80})	02	18	05	08	08	15	44***	40***	30**	
Unit Effectiveness (X_0)	10	01	17	02	05	09	21*	05	12	35***

* P .05
** P .01
*** P .001

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participation in decision making (X_{13}). The direction of causality is consistent with other studies examining the technology-structure relationship (see Fry, 1982). The path coefficients leading from the non routine technology variable to centralization ($P_{11,40}$ ~ .30)and formalization ($P_{12,40}$ ~ .57) are statistically significant at less than the .01 level (Table 7.3). These path coefficients indicate that for each increment increase in non-routine technology, centralization and formalization decrease by .30 and .57 units, respectively. The relationship between technology and participation in decision-making, however, was not statistically significant. Overall, these relationships suggest that groups or units with non-routine technology are organically structured, while more routine technologies employ more mechanistically oriented structures. The lines among centralization, formalization and participation in decision-making in Figure 7.1 are the notation for implying that the model does not assume causality among these factors. This is a logical assumption since all three factors are considered to be dimensions of unit structure.

Similar to the Tushman/Nadler model, a causal relationship between the structural dimensions and the accessibility/quality of information sources is indicated. Note, however, that this model is concerned

with only inter unit information sources. The reason for this is that the correlation matrix in Table 7.4 indicated that unit effectivenss had a negative relationship with inter unit dependence ($p < .05$) and inter unit coordination ($p - .001$). These relationships suggest that the dynamics among units within the organization have some effect on individual unit effectiveness. Hence, focusing on an inter-unit information flow seems appropriate. However, only the path coefficient between the structural dimension of participation in decision making and accessibility/quality of inter-unit information was statistically significant. That is, the more unit members are allowed to participate in the unit's decision making activities, the greater the perception that inter unit information sources are accessible and of high quality.

Two other interesting and significant relationships concerning structural dimensions warrant discussion. These relationships are interesting in that they imply that the structure of the unit will influence the perception of other factors. For instance, the greater the formalization within the unit (i.e., the extent written rules and procedures exist), the greater the perceived predictability/ controllability of the environment. Centralization within a unit was negatively related to inter-unit information requirements. That is,

where decision making authority rests with upper management, unit members apparently have fewer inter-unit information requirements (but tend to have higher information requirements from the manager, p - .06). Thus, unit structure has important implications on the perceptions of unit members.

The correlation matrix in Table 7.4 indicated that accessibility/quality of inter-unit information sources was correlated with the predictability/controllability of the environment and the extent of inter-unit dependence. The causal model of Figure 7.1 suggests that the extent to which units are interdependent and the degree to which the environment is seen as predictable/controllable are dependent on the accessibility/quality of inter-unit information sources. The rationale for this causal relation is based on information theory, where information has the property of reducing uncertainty (see section 2.3.2). That is, if inter-unit information sources are easily accessible and of high quality (high information processing potential), then the status of another unit's activities is better known, lowering uncertainty levels. The lower uncertainty levels concerning the activities among units results in a corresponding lower level of perceived inter-dependence. For predictability/controllability of the environment a similar rationale

applies. The correlation matrix suggested that R&D units obtain information concerning the external environment from other sources within the organization. If the inter unit (or intra organizational) information sources are easily accessible and of high quality, then information about the external environment is available to the unit, lowering the level of uncertainty. The data bears out this relationship in that the path coefficients are both significant and in the predicted direction.

The formulation shown in Figure 7.1 implies that inter-unit information requirements are dependent upon three factors: inter-unit dependence, centralization of the unit structure (discussed above), and predictability/controllability of the environment. However, the path coefficient from predictability/controllability was not statistically significant.

The degree of difference between inter-unit information requirements and accessibility/quality of inter-unit information sources defines the "degree of difference" variable, X_{13}. Hence the path coefficients leading to X_{13} are, of course, significant.

The formulation in Figure 7.1 proposes that inter-unit coordination (X_{80}) is dependent on three variables: inter-unit dependence (X_{60}), inter-unit information requirements (X_{23}), and

"degree of difference" (X_{13}). However, the path coefficient for the "degree of difference" variable was not statistically significant. The model suggests that the more a unit is dependent on other organizational units and/or has greater inter-unit information requirements, the greater the extent of inter-unit coordination.

Unit effectiveness (X_0) is proposed to be dependent on three factors as shown in Figure 7.1: the extent of inter-unit dependence (X_{60}), the extent of inter-unit coordination (X_{80}), and the "degree of difference" variable (X_{13}). The basis for these causal relationships is from previous research on R&D which indicated that the degree of inter-unit communication was correlated with unit effectiveness (Tushman, 1977; Allen, Lee and Tushman, 1980). However, only the path coefficient from inter-unit coordination to unit effectiveness was statistically significant (p = .008). Note, too, that the relationship was negative. That is, those R&D units employing greater amounts of inter-unit coordination tended to be less effective. An explanation for this result is offered below.

As mentioned above, the rationale for assuming the causal relationships for unit effectiveness shown in Figure 7.1 was previous research which indicated that inter-unit information flow was a critical factor influencing R&D performance. However, the negative

relationship between inter-unit coordination and unit effectiveness was not consistent with the theory. That is, a positive relationship is expected between unit effectiveness and inter-unit coordination if inter-unit communication flow is a critical factor for R&D performance. Although the data does indicate a positive relationship among inter-unit dependence, information requirements, and coordination, inter-unit coordination did not significantly increase the inter-unit information source accessibility/quality. This result would explain the relation between coordination and unit effectiveness under conditions of high inter-dependence, where inter-unit information flow is essential. However, the negative relationship between inter-unit coordination and unit effectiveness was strong even where inter-dependence was low. This result suggested that the model was not adequately addressing the empirical relationships.

Recalling that inter-unit coordination is essentially control mechanisms used to integrate the activities of organizational units, an explanation can be developed for the apparent anomaly in the empirical data relationships. Since R&D units reported they were relatively independent of other organizational units (see Figure 5.3), it is expected that relatively little inter-unit coordination or few organizational control mechanisms are necessary to maintain effective

performance. That is, if the units are performing adequately, little organizational or inter unit coordination is necessary. However, if a unit is not meeting its technical objectives, schedule milestones or budget constraints, organizational control mechanisms may be implemented. Thus, organizational controls may require increased coordination with "staff" units (e.g., finance) and the formalization of relationships (e.g., schedules or lateral relations) with other organizational units having a dependency relationship with the less effective unit. Thus, units which are not performing adequately (that is, are less effective) have a greater extent of inter-unit coordination exerted upon them from the organization. This rationale would explain the negative relationship between coordination and unit effectiveness, implying that coordination is the dependent variable and unit effectiveness the independent variable, which suggests the causal relationship in Figure 7.1 be reversed.

Figure 7.2 presents the revised formulation with the new causal relationship identified between inter-unit coordination and effectiveness. Note that the "degree of difference" variable has been eliminated since it has no significant correlation with any other variable. The model in Figure 7.2 has inter-unit coordination as the

final dependent variable and unit effectiveness as another initiating variable. That is, no variable within the model has an influence on unit effectiveness; all influences on unit effectiveness result from variables outside of this model. The path coefficients within the revised formulation are all statistically significant at a probability level of .05 or smaller.

2
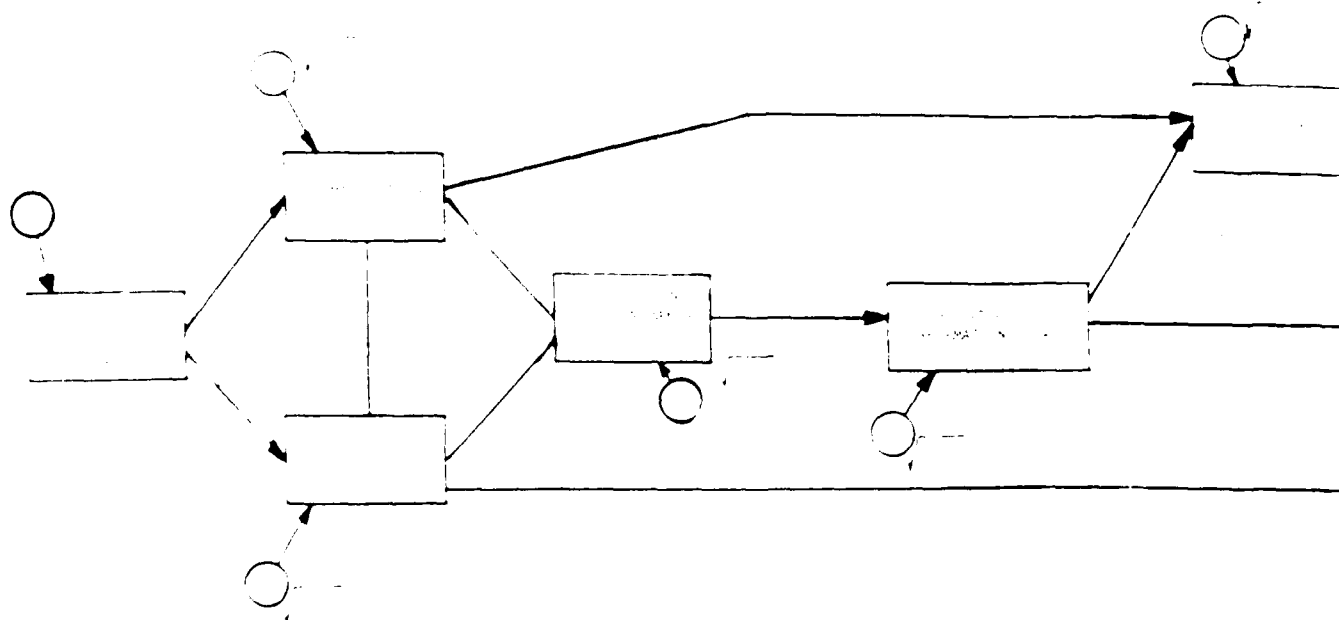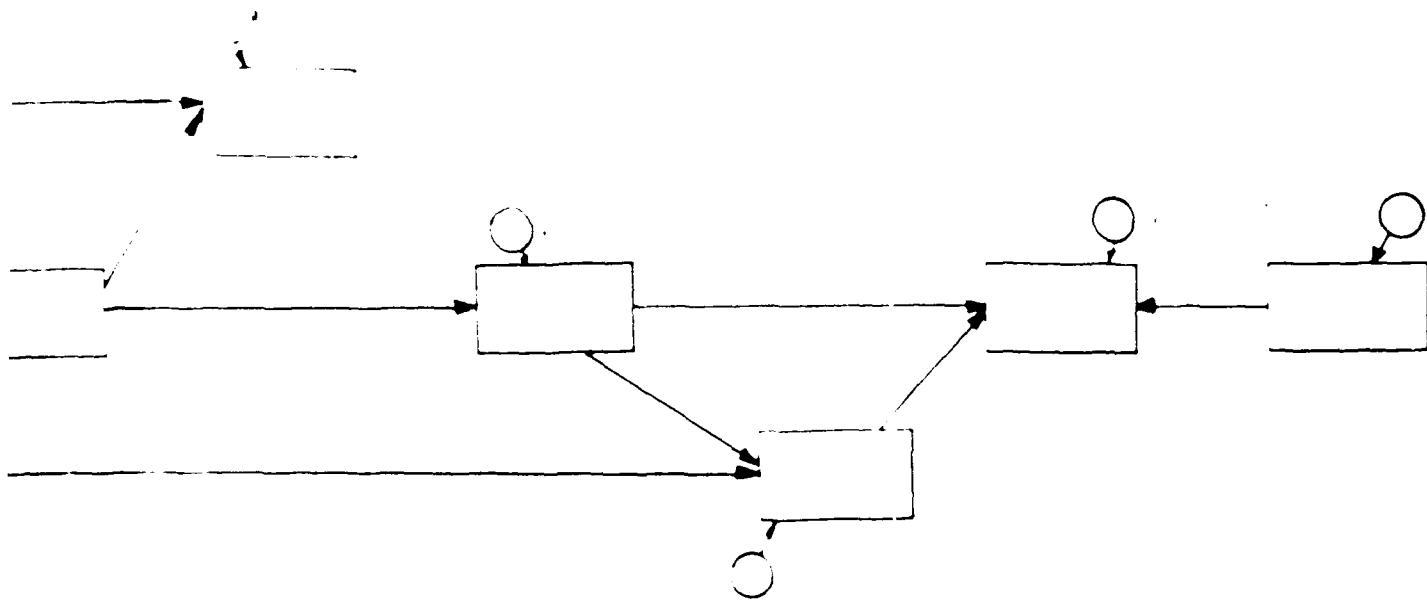
7.3 Summary of Empirical Formulation

The purpose of this revised formulation was to examine and interpret the significant correlations or relationships found within the empirical data. The effectiveness measure for the R&D units was not found to be significantly correlated with any of the variables measured. However, the empirically significant relationships within the formulation provide the following inferences about the dynamics of R&D units:

1. The technology-structure relationship was confirmed, in that non-routine technology was associated with organic unit structures and routine technology was related to more mechanistic unit structures.

2. The dimensions of unit structure had differential influences on other variables within the model. In particular, unit centralization had a negative influence on inter-unit information source requirements, unit formalization positively influenced the extent to which the external environment was perceived as predictable/controllable, and participation in decision-making had a positive effect on the accessibility/quality of intra-organizational information sources.

3. Accessibility/Quality of intra-organizational information services has an effect on the perception of environmental predictability/controllability, and inter-unit dependence. That is, with greater accessibility to and quality of information sources (i.e., the operationalization of information processing capabilities) the lower the uncertainty levels. This result is consistent with information theory, which states that information and uncertainty are mathematically related.

4. Greater degrees of inter-unit dependence lead to greater inter-unit information requirements, which further results in greater inter-unit coordination or integration activities.

5. R&D units, relatively speaking, report low degrees of inter-unit dependence and, consequently, are subject to relatively low levels of inter-unit coordination. However, when R&D units are not effective (including not meeting technical goals or specifications, are over budget, or behind schedule), inter-unit coordination mechanisms appear to be are activated or increased.

The following and final chapter summarizes the study results and discusses the implications of the empirical results for the literature concerned with R&D organization and management.

CHAPTER 8

SUMMARY and DISCUSSION

8.1 Introduction

The management of Research and Development activities is an extremely complex and challenging undertaking because R&D is a creative process taking place in a turbulent environment. Such a situation suggests that an R&D project team or unit requires an organizational design which will permit it to attend to the inherent uncertainties and risks (technical and commercial) it faces in performing its activities. Indeed, project and matrix organizational forms were developed in the 1960's and 1970's for the management of R&D activities. Although these organizational forms are often adopted, they have not always been implemented properly, nor have they demonstrated consistent success in improving organizational effectiveness (Baker and Wilemon, 1977; Gunz and Pearson, 1977; Knight, 1977; Davis and Lawrence, 1978; Pywell, 1979; Vasconcellos, 1979; Cleland, 1980; McCarney, 1980; Rowen, Howell and Gugliotti, 1980; Greiner and Schein, 1981; Kur, 1982; and, Evans 1982). However, the fault can not entirely be placed on practitioners because, until recently, the conceptual framework upon which the design of complex organizations is based had not been well developed. The

conceptualization of organizations as information processing systems by such researchers as Galbraith (1971) and Simon (1973) offers a promising conceptual back drop from which to view the design of complex organizational structures. The purpose of this research is to examine the information processing approach to organizational design within an R&D field setting as a way to increase understanding of organizational design.

A substantial portion of the literature concerned with the study of the R&D process has been devoted to an examination of the information flow or communication process within R&D groups (for a recent review of the relevant literature see Epton, 1981 or Paolillo, 1982). Allen (1970) suggested that R&D units need to have contact with information sources outside of the laboratory in order to maintain a "state of the art" awareness of recent technological breakthroughs. In his research, Allen found evidence of a "technological gatekeeper", or organizational "boundary spanner" who facilitated the transfer of extra-organizational information to other members within the organization. More recently, Tushman and Nadler (1978), building on the work of organizational researchers, and borrowing from information theory, proposed an information processing model of organizational design and effectiveness. Underlying this model is the proposition

that organizational units must process information in order to reduce uncertainty to a level where problem solving and/or decision making can be performed effectively. The Tushman/Nadler model proposes that certain contextual factors (technology, environment and inter-unit dependence) influence the extent of uncertainty being faced by an organizational unit, which in turn, determines the unit's information processing requirements. The model also proposes that organizational design (i.e., unit structure and inter-unit integrating mechanisms) will determine the ability of a unit to process information. Ultimately, the model proposes that unit effectivenss is determined by matching or fitting an appropriate organizational design so that the information requirements facing a unit.

Another portion of the literature on the R&D process has pro-posed that Research and Development are two different subprocesses, implying that different management approaches may be required (Allen, Lee, and Tushman, 1979). Abetti (1983) has argued that Research is concerned more with the inventive process (technology expansion) and that Development activities are oriented more toward the innovation process (systems or product development). Several studies have found that the nature of a unit's communication activity varies with the specific function being performed; that is, research vs. development

(Tushman, 1979; Allen, Lee, and Tushman, 1980; and, Tushman and Katz, 1980). Tushman/Nadler (1980) suggest that although the different orientations of research and development will create different information requirements and, thus, should employ different organizational designs for the efficient processing of information the basic model will still be valid.

With this background, this study sought to examine the infor mation processing approach by:

1. operationalizing the Tushman/Nadler model using constructs from previous organizational research (presented in Chapter 4);

2. testing the relationships within the model using an R&D field setting as a data source (presented in Chapter 5 and 6); and

3. examining the consistency between the Tushman/Nadler model and the empirical data (presented in Chapter 6).

Finally, this chapter draws conclusions and makes implications, based on the empirical evidence, in the areas of:

1. organizational theory, and

2. computer-based information system design

8.2 Review of the Results

The variables within the information processing model of organizational design and effectiveness formed the basis for the study. As

discussed in Chapter 4, the measure of the variables was determined from an average of the variable dimensions, which themselves were derived from or based on previous research and confirmed by a principle components factor analysis. The group or unit was used as the unit of analysis, averaging the variable scores across unit members. An analysis of variance was performed on several units, examining the consistency of unit member perceptions of the variables. For those units examined, the results of the ANOVA generally did not provide sufficient evidence to reject this meth- odology. The sample of units was randomly selected from a population of six Air Force System Command organizations. The sample was strat- ified into two categories corresponding to Research and Development. A total of 80 R&D units were included in the analysis; 42 groups were involved in research activities and 38 units were responsible for development activities. Data was gathered from surveys personally administered to the technical personnel within the organizations and returned anonymously to the investigator. In approximately 80% of the units, all members within the unit were asked to participate. In cases where all unit members were not available for participation (primarily in the larger units), a random sampling of unit members was used. In all cases, a unit was included in the study only if a

minimum of 50% of the distributed surveys were com- pleted and returned by the unit members. A total of 551 individual responses from the 80 units were included in the study (65% response rate). Effectiveness measures for the units included in the study were obtained from upper levels of management. All units included in the analysis had a minimum of two evaluators. The managers demonstrated a high degree of consistency in the ranking of the units (Kendall statistic generally showed a significance level of .05 or better).

8.2.1 Hypothesis Sets 1-3

The first three sets of hypotheses concerned differences between research units and development units for the contextual factors within the information processing model. The three contextual variables (organizational technology, environmental uncertainty, and inter-unit dependence) were each composed of two dimensions, providing a total of six contextual dimensions. Research units were found to be significantly different from development units on three of six contextual dimensions, providing partial support for these hypothesis sets. In comparison to development units, research units perceived more task exceptions (task variety), were less dependent on other organizational units, and, were less depended upon by other

organizational units. However, for three contextual variables (organizational technology, environmental uncertainty, and inter-unit dependence) of the information processing model, both research units and development units can be thought of as existing in a contextual situation where the technology is non-routine, the environment is uncertain, and the inter-unit dependence is low. Figure 8.1 illustrates the contextual situation for both research and development units in terms of the model shown in Figure 3.2, which suggets that research units and development units perceived relatively similar contextual situations.

8.2.2 Hypothesis Sets 4-6

Hypothesis sets 4-6 examined the relationship between the contextual factors within the information processing model and information source requirements. Information sources were differentiated by four categories: Supervisor/Manager, Unit Members, Others in the Organization (but outside of the unit) and, External to the Organization. Significant regression equations were found for four of the six contextual dimensions. Generally, the relationships were in the predicted direction. That is, the greater the complexity/dynamism associated with the environment, the greater the external information

FIGURE 5-1

CONTEXTUAL SITUATION FOUND FOR USAF R&D UNITS

R&D UNITS

CONCEPTUAL STAGES
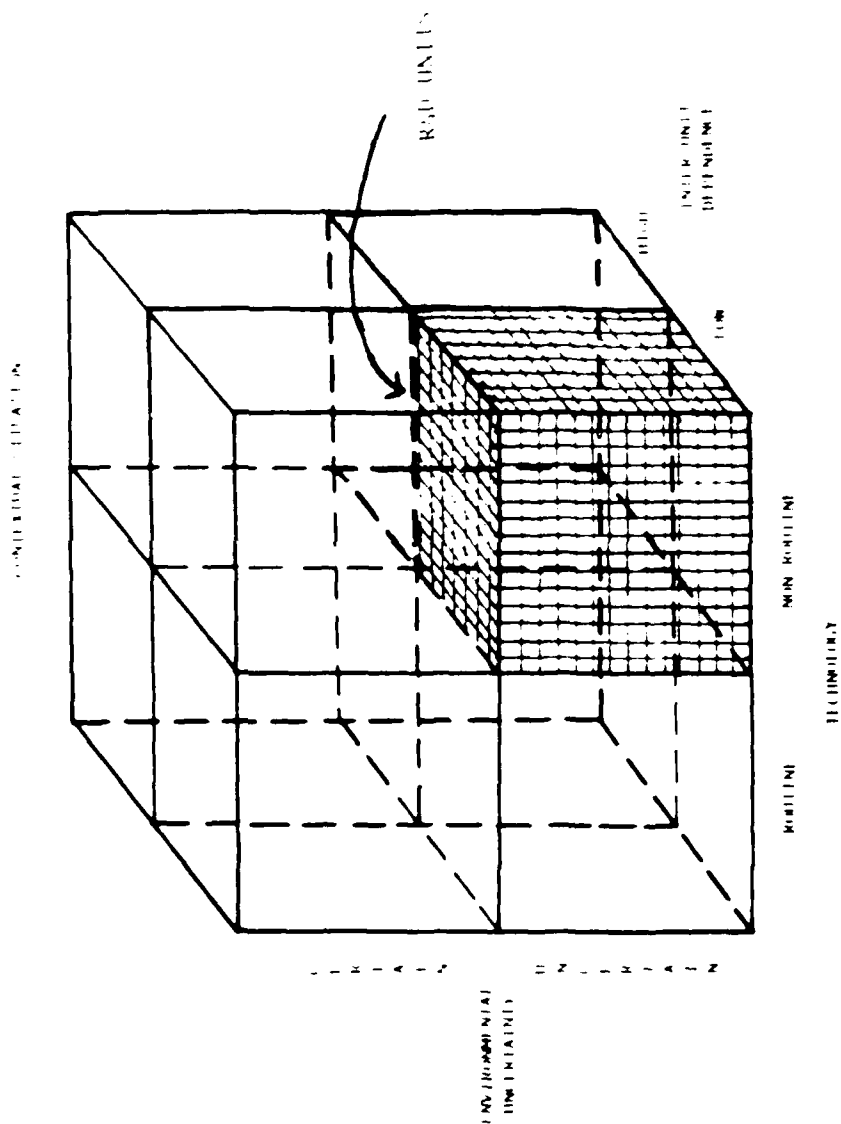
required and, the greater the dependency between units, the greater the inter unit information required.

Contrary to expectations, a significant inverse relationship between predictability/controllability and external information requirements was obtained. That is, the more the environment was perceived as unpredictable/uncontrollable, the less the need for external information. Apparently, if the environment is perceived as unpredictable and uncontrollable, information from the most reliable of external information sources may still appear as equivocal and, hence, of little utility to the unit. The lower value placed on information may result in less of a requirement for external information.

A significant but negative relationship was found between the extent to which other organizational units are perceived to be dependent upon a unit and the information required from the unit manager. An explanation for this relationship may be that in situations where other organizational units are dependent upon a unit, unit members may temporarily be assigned to the dependent unit, responding to that unit's information needs. Hence, the information required from the original unit manager is reduced. Note also that this explanation would suggest that the information required from

other unit members should also be reduced. The data suggests that this tends to be the case, in that information required from group members decreases with higher levels of other unit dependence (p = .09).

Regressing information source requirements on the contextual dimensions of organizational technology (exceptions and analyzability) did not yield significant results. However, this may be due to a restriction in the data range that was encountered for this variable.

8.2.3 Hypothesis Sets 7-8

The relationship between the organizational factors (unit structure and inter-unit coordination) and the accessibility/quality of information sources was explored in hypothesis sets 7 and 8, respectively. Two of the dimensions of unit structure, centralization and participation in decision-making, had significant relationships with the accessibility/quality of information sources. The extent of centralization associated with a unit's structure (that is, the location of authority to make decisions in the unit), was negatively associated with the accessibility/quality of information from both the unit manager and unit members. Participation in the decision-making process (that is, the ability to have input to the decision-making

process), was positively related to the accessibility/quality of all information sources. The formalization dimension of unit structure (extent to which written rules and procedures exist within the unit) was not significantly related to the accessibility/quality of any information sources.

Inter unit coordination concerns the extent to which the activities between organizational units are integrated or controlled. Hypothesis 8 proposed that inter-unit coordination mechanisms (rules/procedures, plans/schedules and mutual feedback) would be positively related to the accessibility/quality of inter-unit information sources. However, the statistical analysis did not yield significant results for any information source. Thus, hypothesis 8 was not supported.

8.2.4 Hypothesis 9

The absolute value of the degree of difference between the information required from a source and the accessibility/quality of that information source was used to operationalize the degree of fit between information processing requirements and capabilities proposed in the Tushman/Nadler model. The functional relationship between the "degree of difference" measure and unit effectiveness is illustrated

in Figure 5.4. However, as the figure shows, nearly 85% of the units reported situations where information source accessibility/ quality exceeded information source requirements thus restricting the range of the variable. This restriction in range essentially reduces the hypothesis test to units who report excess information processing capability. However, even the range for units reporting excess capabilities was restricted, thus reducing the ability of the study to suggest a relationship between the variables if it did, in fact, exist.

The regression equations generated using the restricted data range were significant for the Supervisor/Manager as information source (p = .02 level of significance), and approaching significance for unit members (p = .07 level of significance). The relationship was negative as the hypothesis predicts, suggesting that those units who had small differences between the information required from intra-unit sources and the accessibility/quality of intra-unit information sources tended to be more effective. The regression equations examining the relationship between unit effectiveness and the "degree of difference" measure for intra- and extra-organizational sources were not significant. These results provide only limited support of Hypothesis 9.

8.2.5 Path Analysis

A path analysis was performed, in order to examine the consistency between the empirical data and the Tushman/Nadler information processing model. The path analysis of the model shown in Figure 6.3 indicates only three path coefficients to be significantly different from zero. The significant paths were between the following pairs of variables: R&D and Inter Unit Dependence, R&D and Inter-Unit Coordination, and Unit Structure and Accessibility/Quality of Information.

Additional, but separate, path analyses were performed at both the variable and dimensional levels for research units and for development units. The path analyses performed at the variable level for research units and for development units did not yield any additional evidence in support of the Tushman/Nadler model. However, several differences in variable relationships were noted between research units and development units. These differences between research and development units, identified in the more aggregated variable level path analysis, led to a path analysis at a dimensional level which yielded several significant results in support of relationships proposed within the Tushman/Nadler model. However, the path analyses results for research units and development units were not the same. In particular, the

effect of the contextual variables on information source requirements
differs between research units and development units. For instance,
in research units, high environmental complexity/dynamism resulted in
significantly greater extra organizational information requirements.
This finding is consistent with the results of researchers studying
the relationship between environmental uncertainty and
boundary spanning activity (Leifer and Huber, 1977, and Leifer and
Delbec, 1978). However, in development units, increases in
environmental uncertainty resulted in significant increases in
intra-unit information requirements. An interesting explanation for
this result comes from Taylor (1975) who performed research in a
similar setting. Taylor speculates that the communication pattern may
be a consequence of the training undergone by the development
engineer. That is, the development engineer is trained to solve
problems out of his own resources of know-how and is not taught or
encouraged to do "outside research." The important point is that the
group dynamics underlying research units and development units appear
to be different. That is, the contextual variables or dimensions
appear to have different effects on the information source
requirements which suggests that the information processing model
relationships, as currently proposed, may not adequately be capturing

the dynamics affecting information requirements.

Since the Tushman/Nadler model did not adequately explain the variable and dimensional relationships, an empirically-based model was developed out of the significant relationships found within the data (Figure 7.2). Several results from this model, discussed in Chapter 7, warrant mention here.

1. The relationship between technology and structure was highly significant, suggesting that units having more non-routine technologies were organized around more organic structures.

2. The dimensions making up unit structure had different effects on other variables within the model. For example, centralization was found to have a negative relationship with the need for information from other organizational units. However, the information required of the manager tended to be greater in highly centralized organizations.

3. The accessibility/quality of inter-unit information sources have a positive relationship with environmental predict-ability/controllability and a negative relationship with inter-unit dependence. That is, where information sources are easily accessible and of high quality, the uncertainty associated with contextual factors is lowered. This result is consistent with the concept that greater information processing capability lowers uncertainty.

4. Greater degrees of inter-unit dependence lead to greater inter-unit information requirements which in turn result in greater inter-unit coordination.

5. R&D units report relatively low degrees of inter-unit dependence and, consequently, are subject to relatively low levels of inter-unit coordination. However, when R&D units are not performing adequately, organizational controls (e.g. inter-unit coordination mechanisms) are increased.

In general, the alternative formulation suggested different ways of looking at the variables of requirements and capabilities than those suggested by Tushman and Nadler.

8.3 Implications of the Study Results

Although it is inappropriate to generalize from a single study, especially from a study focusing on a particular field setting, the results from this study can be synthesized with other research for purposes of theory development. This section discusses implications of the study's results for the areas of organizational design and organizational information systems. The first subsection discusses an expansion of the Tushman and Nadler (1978) model, suggesting that the process of organizational design be viewed as an information processing control system. The second subsection examines the role of computer-based information systems within the R&D organization. The basic idea behind this section is that both organizational design and information systems are management control systems, influencing the information processing behaviors of the organization. To be used effectively, organizational design and information systems need to complement each other.

8.3.1 Organizational Theory

This study operationalized and tested the Tushman/Nadler information processing model of organizational design and effectiveness using 80 R&D organizational units at 3 geographical sites within the Air Force Systems Command. The statistical analysis presented in Chapter 5 provided limited support of the Tushman/Nadler operationalized model. A restriction of range in the data may explain the failure to find statistical support for some of the relationships. However, several statistically significant relationships were found that were not proposed by the Tushman/Nadler framework. Furthermore, a comparision of path analyses performed for research units and development units suggested that different relationships existed among the model variables. These results imply that the Tushman/Nadler information processing model did not fully predict many of the found interactions occurring between variables.

8.3.1.1 Implications for Organizational Design Models

Contingency theorists view organizational design as a function of certain contextual factors; typically technology, environment and size (Ford & Slocum, 1977). Because advocates of each contextual factor have taken the position that their factor determines for the

organization what its design must be, this approach has been called
the contingency or imperative school of thought on organizational
design (Jackson & Morgan, 1978). The Tushman/Nadler model, borrowing
from information theory, proposes that these same contextual factors
are responsible for creating the uncertainty facing an organizational
unit, which in turn, defines the organizational information processing
requirements. The Tushman/Nadler model also proposes that unit
structure and inter unit coordination mechanisms determine the ability
of the organization to process information. Ultimately, they propose
that unit effectivenss will be enhanced in those organizational units
whose information processing capabilities are "fitted", or "matched",
to their information processing requirements.

The Tushman/Nadler information processing model of organizational
design and effectiveness, as in the "imperative" models, does not
explicitly identify relationships or interactions among the contextual
and organizational factors. The empirical results from this study
suggest that these relationships do exist. Other studies have
resulted in similar find gs. For example, Huber, O'Connel and
Cummings (1975), in finding that organization structure affects
perceived environmental uncertainty, suggest that reciprocal causation
between uncertainty and organization structure may be operating.

Hence, the Tushman/Nadler model is, in effect, a rational or prescriptive approach to organizational design and effectiveness. As a descriptive model of organizational design, the Tushman/Nadler model apparently may be inadequate.

What the Tushman/Nadler model excludes is that individual unit members perceive, and hence are effected by, both the contextual and organizational factors. That is, unit members, influenced by their own perceptual processes, will ultimately "determine" the context in which they work. Furthermore, organizational factors will influence the perceptual process of individuals by controlling the information they receive. Thus, a descriptive model for organizational design needs to incorporate the reciprocal effects between the unit members' perceptual processes and the con extual and organizational variables.

Child (1971) was perhaps the first to suggest that the perceptual process of organizational members will play a role in the design of the organization. Child saw the manager or administrator as the missing link in the contextual models, suggesting that his/her perceptions of the contextual factors will influence the organization's design. Montanari (1978) claims that the contextual models of organizational design (see Figure 2.3) have been capable of explaining only 50 60 percent of the variability in organization

structures and also argues for a more comprehensive paradigm that includes managerial discretion. Porter, et. al. (1975) state that:

> ...neither technology nor size completely dictates how much standardization, specialization, centralization, etc. must exist in an organization.
>
> ...the structuring of activities is modifiable and subject to the voluntary determination by those making the decisions in the organization.

These statements imply that although the contextual variables (technology, etc.) will constrain the range of structural alternatives available, the manager does have some influence in determining how the organization is tailored to accomplish its purpose. Consistent with this view, Bobbit and Ford (1980) expand the contextual or imperative models to allow for the individual member effects on organization design. That is, Bobbit and Ford consider the unit members as an integral part of the process of organizational design. Figure 8.2 presents a modified version of the Bobbit and Ford model, demonstrating the relationship of the decision maker or manager to the contextual variables, organization design and effectiveness. This model includes a "feedback loop" between components of the model,

suggesting that the process of organizational design and effectiveness can be viewed as a control system. The Bobbit/Ford model essentially adds three variables to the contextual model of Figure 2.3: (1) the current organizational structure, (2) the organizations' members, and (3) the manager's role.

For existing organizations attempting to change or modify its design, the current structure may present an obstacle. March and Simon (1958) suggest that organization structure may become an end in itself. For example, a bureaucratic structure would be expected to be self-perpetratuating, avoiding change to maintain its well-defined rules, procedures, and lines of authority and responsibility. Thus, the current organizational unit structure must be considered as a factor influencing organization design. The transformation from one organizational structure to another is a complex process and is addressed in the organizational development literature.

The influence of organizational members on organizational structure is also modeled through a feedback process. That is, organizational structure has been shown to influence employee satisfaction (Cummings and Berger 1976; Porter and Lawler, 1965). Expectancy theory (Vroom, 1964) suggests that low member satisfaction will eventually lead to lower performance and, hence, a less effective

FIGURE 8.2

SIMPLIFIED FORM OF THE BOBBIT AND FORD (1980) MODEL

OF ORGANIZATIONAL DESIGN
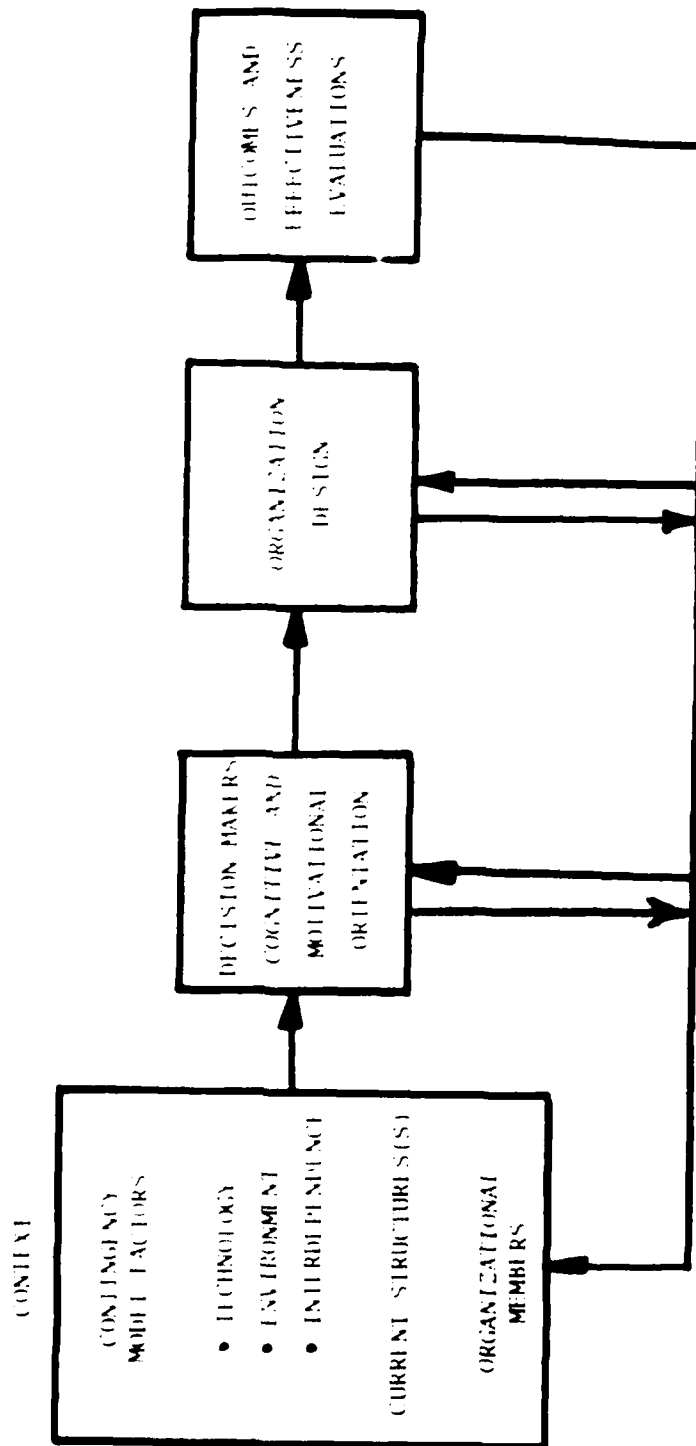
organization. Therefore, individuals within the organization represent another factor influencing the organizational structure or design (Bobbit and Ford, 1980).

The degree to which a decision maker or manager can influence organizational form stems from his/her ability to make structural transformations. The alternative transformations selected will be influenced by the decision maker's personality, specifically his/her cognitive and motivation orientation. That is, the alternative transformations will be a function of how the manager interprets or perceives the contextual situation, which is dependent on his/her capabilities. Bobbit and Ford (1980) refer to the cognitive orientation as encompassing those factors that relate to the information processing capabilities and modes of the manager, and the motivational orientation as providing the "rationale underlying the manager's choice".

In summary, the empirical data from this study indicated that the Tushman/Nadler model was not adequate in explaining the empirical relationships. The conclusion is that their model is not descriptive of the process of organizational design and effectiveness, at least in the setting used for this study. Recent literature concerned with the determinants of organizational design have proposed that an

organization's members, particularly managers, are important components in the process of organizational design (Child, 1971; Montanari, 1978; and Bobbit and Ford, 1980). These researchers, whose conceptual models include the effects of "individual differences" as well as the contextual factors on organizational design, present a more complex and interdependent model than those models offered by the imperative or contingency-based approaches. The empirical relationships identified in this study's revised formulation imply that a more complex, descriptive model other than that proposed by Tushman and Nadler (1978) will be necessary to understand the process of organizational design and effectiveness. A model of organizational design which includes "individual differences," such as that proposed by Bobbit and Ford (1980), warrants empirical investigation.

8.3.2 Information Systems

The last several years have seen a large growth in "information management" technologies of office automation, teleprocessing, and computers, suggesting that we are moving further into the "information age." The full impact that these information management technologies will have on today's organizations is still being determined. Yet the literature suggests that the design and implementation process for the

introduction of computer based information systems into the organization remains an area of major concern (for example: Lucas, 1975; Ginzberg, 1978; and McKenny and McFarlan, 1982).

8.3.2.1 Organizational and Information System Designs

Viewing organizations as information processing systems may offer the conceptual backdrop from which to view the design and implementation of computer based information systems. Galbraith (1971) proposed that use of information systems is a "coping mechanism" employable by organizations to increase information processing capabilities, allowing the organization to deal with the uncertainty facing it. A logical extension to the Tushman and Nadler information processing approach would be that the computer-based information system must be designed to fit to the information processing requirements facing the organization and interacts with the organizational design. This extension suggests that both the organizational design and the computer based information systems are complementary management tools that can influence organizational information processing behavior. However, the information processing approach also implies that the design of an information system (e.g., access to a database) should be compatable with the organizational

design. Lucas (1981) states that the introduction of a computer-based information system can affect the distribution of power within the organization. That is, if the information system design provides access to a common database, the lines of authority, set up by the organizational design, may be disrupted, resulting in a less effective organization.

For instance, in a development unit the project manager is responsible for making design trade-offs, typically among the project parameters of technical performance, schedule, and cost. If an engineer, responsible for the technical aspects of a project, has access to cost and schedule data through the information system, he may determine for himself/herself the merits of alternative technical designs without feeling the need to consult the project manager (who remains responsible for the project). This may be good or bad depending on whether the engineer has all the information upon which the decision is to be based and has competence to weigh the alternatives. In this way, the computer-based information system may alter the information flow and decision process intended by the organizational design.

Likewise, the relationships defined by the organizational design may influence the data going into the information system. Huber

(1982) states that information or message routing and summarizing, as well as message delay and modification, regularly occur within organizations, which can effect the performance of the organization's information system. For instance, consider a situation in a research setting where a scientist, finding that an experiment is running a little long, inputs the small delay into the information system to inform his/her project manager. However, the laboratory director has instituted a centralized organizational design to ensure "proper" management control. Taking full advantage of the "information management" technology, the director has a "flagging" program that immediately alerts him/her to any and all projects having problems. Before long, the laboratory director is on the telephone calling the project manager to find out what the manager is doing about the problem which the manager may or may not know of. It won't take many similar experiences like this one before the scientist learns how to delay or modify information - exactly the opposite purpose for installing the computer-based information system and the organizational design.

In summary, the organizational design and the computer-based information system need to be compatible, since they both influence the information flow and communication behaviors of the organization.

The information processing approach provides a conceptual reference point for the study and development of computer-based information systems within the organization.

8.3.2.2. Information Systems in R&D

The complexities and dynamics of managing R&D activities has brought about innovations in management techniques including: project planning and control techniques, work breakdown structures, and project/matrix organizational forms. However, computer-based management information systems (MIS) have not been an integral part of R&D organizational systems. Karger and Murdick (1971) suggest that the development of an MIS for R&D has been neglected because of the R&D manager's focus on technical performance and technology rather than exploiting the possibilities available from better management of the function. Note that the majority of R&D units within this study report information source accessibility and quality as more than adequate to contend with information source needs. This suggests that information is potentially available from a source but does not necessarily imply that the required information is processed by the unit. That is, if too much "non-relevant" information (often administrative in form) is available from various sources the

individuals within the unit may not be able or elect to "absorb" or
"intepret" the information in an efficient manner. Thus, the utility
of computer-based information systems within the R&D context may not
be in providing a greater quantity of information to an already
saturated system, but to improve the efficiency of information
processing within the unit (e.g., tracking and reporting of project
parameters, providing decision support systems for semi-structured
problems, database management systems which allow appropriate levels
of detail for information retrival and review). In addition to
keeping track of and reporting on the project or units performance, an
R&D MIS, appropriately designed, can be used to increase the
integration between organizational units. That is, computer-based
information systems can be used to facilitate inter-unit coordination
or integration (Moynihan, 1982).

The importance of a computer-based information system within the
R&D organization is highlighted by the empirical results of this
research. This study found that intra-organizational coordination or
integration was negatively related to unit effectiveness, suggesting
that organizational controls were increased in these R&D units having
performance problems. That is, R&D units are apparently "loosely"
coupled to the organization until effectiveness is degraded to a point

where upper levels of management become involved and imposes greater
controls. The situation at this point may or may not be salvageable;
nevertheless, management institutes tighter organizational control
(coordination). This is not a surprising occurrence in an
organization where unit managers are expected to work their problems
out for themselves. In such a setting, going "up the chain of
command" to resolve your unit's problems is not always a career
enhancing experience. Thus, the norm established within this setting
is to "ride out the problem" (with the hope that another assignment or
promotion comes along before things get too bad). The result of this
is that upper management often does not become aware of the problem
and, hence, get involved until the situation has already
deteriorated. An appropriately designed and implemented
organizational information system (that is, organizational design and
computer-based information system), tailored to the particular needs
of the research units and development units, may aid in reducing the
frequency with which the above situation occurs.

8.4 Suggestions for Future Research

In the course of performing this study, the concept of
organizations as information processing systems was offered as a

theoretic thread linking the processes of organizational and computer based information system designs. The need for a common conceptual basis between these areas is increasingly evident with the development and introduction of "information management" technologies into the o ganization (office automation, telecommunications and computers). With a common conceptual basis to work from, the design and implementation of such information systems within the organization is likely to be facilitated.

However, the concept of organizations as information processing systems requires further empirical research and development. The results of this study suggest that the Tushman and Nadler (1978) approach to organizational design may not be an adequate descriptive representation of organizational design in actual field settings. Thus, a potential research study is in further conceptualization and, eventual, operationalization of a model of organizational design which includes the "individual differences" variable.

Another area of research potential is an investigation of the impact of computer based information systems on organization structure and design. Several researchers have looked at this issue including: Robey (1977, 1981), Pfeffer and Leblebici (1977). However, a more detailed conceptualization between the appropriate type or design of

computer based information systems (e.g., centralized or decentralized databases) and organizational form (e.g., project, functional or matrix), based on the information processing approach, would be a contribution to the literature. Another possible study would be an empirical study which compares the information patterns and design of organizations employing "information management" technology to similar organizations without such information systems. Such a study would provide insight into the effect of ogranizational information systems.

In terms of extending this research study, a replication of this study within another contextual setting(s), see Figure 8.1, should provide a range in data needed to adequately test the relationships within the Tushman/Nadler information processing model. A field setting using manufacturing or production units would be appropriate since it may provide a contextual situation opposite that of R&D (i.e., routine technology, certain environment and high interdependence).

Another research project could focus on closer examination of the information flows in research units and development units. This study, consistent with other research, found that when experiencing high environmental uncertainty research groups required more contact with external information sources while development units reported
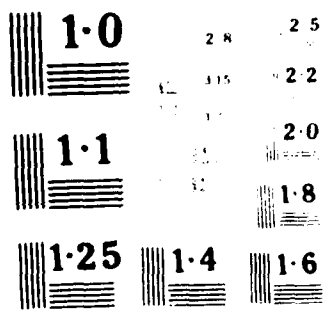
more information was required from the unit manager and members. The methodological issue of how to obtain this data within field settings is no trival matter. Traditionally, this data has reportedly been collected from self report communication logs from each unit member. This log or survey would be administered once or twice a week over a period of several weeks, intending to record the communication ativities for that individual on a given day. A pre-test for this research study found this method unacceptable in gathering communication data for the following reasons:

1. after 3 or 4 administrations of the survey, individuals became disinterested and the response rate began to decrease rapidly.

2. absences from the work place (due to travel, vacation, training, sickness, etc.) proposed serious problems.

3. when individuals did fill out the communication log it was typically at the end of the day, resulting in a number of communications which were apparently forgotten or not recorded. The evidence for this statement came from a comparison of the logs of communication dyads and triads which indicated a low degree of consistency.

Hence, future studies, using similar data collection procedures must be prepared to address these issues. Where possible, unobtrusive measures should be considered or, as suggested by Walsh and Baker (1972), a sampling plan for observational data collection should be devised.

The above mentioned research topics are by no means an exhaustive list. The increasing complexity and sophistication of technology, coupled with pressure for increased productivity from highly trained and expensive specialists, is a challenge for managers of research and development. The need for innovative and effective approaches to the management of R&D activities will continue to increase, providing a challenge to management scientists to develop the sophisticated, yet practical, tools and techniques needed by the technical manager for the management of technology.

APPENDIX A

WORK UNIT MEMBER SURVEY

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE MANPOWER AND PERSONNEL CENTER
RANDOLPH AIR FORCE BASE TX 78150

2 2 FEB 1984

MPCYP

Survey Approval (Capt Triscari)

HQ AFIT/ED

1. A final copy of Capt Triscari's survey has been reviewed and is approved for administration in the Air Force Systems Command (AFSC) selected sites. Prior to survey administration, Capt Triscari must coordinate the survey effort with each local Central Civilian Personnel Office (CCPO) within the AFSC organization.

2. A Survey Control Number (SCN) of USAF SCN 84-17 is assigned and expires on 31 Aug 84. Questions regarding this action can be directed to Mr Charles Hamilton, HQ AFMPC/MPCYPS or AUTOVON 487-2449/6122.

FOR THE COMMANDER

BERT K. ITOGA, Lt Col, USAF
Chief, Research & Measurement
    Division

cc: Capt Triscari

APPENDIX A

R&D Work Unit Member Survey

SCALE	DESCRIPTION
1	Number of Task Exceptions
2	Analyzability of Task
3	Technical/Cost/Schedule Exceptions
4	Technical/Cost/Schedule Analyzability
5	Organizational Change
6	Organizational Complexity
7	Organizational Predictability
8	Organizational Controlability
9	Environmental Change
10	Environmental Complexity
11	Environmental Predictability
12	Environmental Controlability
13	Centralization of Unit Structure
14	Formalization of Unit Structure
15	Specialization of Unit Structure
16	Impersonality of Unit Structure
17	Dependence of Unit on Other Organizational Units
18	Other Organizational Unit Dependence on Unit
19	Extent of Inter-Unit Coordination

R&D Work Unit Member Survey

SCALE	DESCRIPTION
20	Information Needed From Supervisor
21	Information Needed From Group Members
22	Information Needed From Others in Organization
23	Information Needed From Others Outside Organization
24	Accessibility of Supervisor as Information Source
25	Accessibility of Group Members as Information Source
26	Accessibility of Other Organization Members as Information Source
27	Accessibility of Others Outside Organization as Information Source
28	Quality of Information From Supervisor
29	Quality of Information From Group Members
30	Quality of Information From Others in Organization
31	Quality of Information From Others Outside Organization
32	Information Load From Supervisor
33	Information Load From Group Members
34	Information Load From Others in Organization
35	Information Load From Others outside Organization

Your Participation in this Survey

1. What you will be asked :

The questionnaire you have been asked to voluntarily complete will provide data on several factors concerned with your information needs or requirements as well as the ability of your unit to provide you with this information. In addition, you will be providing data on several characteristics of your unit's organizational structure and how your unit coordinates work with other units. Also, you will be asked to give your perceptions on the nature of your work and the environmental factors effecting it.

2. How your responses will be used:

The data you provide will be used to identify a profile of the information processing needs and capabilities of your unit. In this way, your own personal responses will be anonymous. Please be assured that the data you provided will be treated confidentially, both on an individual as well as a unit basis. YOUR PARTICIPATION IS VERY IMPORTANT AND WILL BE SINCERELY APPRECIATED.

3. Returning the Survey:

After completing the survey (it should take about 45 minutes), please seal the survey in the pre-addressed envelop provided. The only identification on the survey or envelop should be your organizational symbol or a number used to identify which unit the response came from. Please return the survey as soon you possibly can, preferably before 15 May 1984.

4. For more information:

You can obtain more information on the nature, scope, and findings of this research by contacting:

Thomas Triscari Jr.
School of Management
Rensselaer Polytechnic Institute
Troy, New York 12181
(518) 266-6452

THANK YOU

RENSSELAER POLYTECHNIC INSTITUTE

SCHOOL OF MANAGEMENT

SURVEY OF ORGANIZATIONAL DESIGN & COMMUNICATION

Thank you for taking time to complete this survey. When responding to the items in it, please keep the following in mind:

ALL RESPONSES ARE ANONYMOUS. Please do not identify yourself. All information will be kept **STRICTLY CONFIDENTIAL.**

THERE ARE NO "RIGHT" OR "WRONG" ANSWERS. Try to answer the items as you really see things. Work quickly but accurately -- your first impression about an item is usually the "best" one.

PLEASE ANSWER ALL ITEMS, IT IS EXTREMELY IMPORTANT THAT YOU ANSWER ALL ITEMS in this questionnaire. You may want to scan a section of items before answering the first of them.

In this survey, the group of which you are part will be referred to as a UNIT. The term UNIT is intended to mean that part of the

for which your immediate supervisor has

responsibility.

For many of the items in this survey you will be given rating scales to use to record your response. Please place the number best describing your reaction to an item in front of that item, in the space provided. The survey is 13 pages long. Completion of this questionnaire should take no longer than 45 minutes.

Thank you for your cooperation.

:	1	2	3	4	5	6
Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly

NATURE OF THE WORK

Using the above scale, to what extent do you agree or disagree with the following statements about the work done in your unit:

_____ 1. The work is routine.

_____ 2. There is a clearly known way to do the major types of work normally encountered.

_____ 3. People in this unit do about the same job in the same way most of the time.

_____ 4. There is an understandable sequence of steps that can be followed in doing the work.

_____ 5. The tasks performed in doing the work differ greatly from day-to-day.

_____ 6. It is difficult to specify a sequence of steps that can be followed in carrying out the work.

_____ 7. Basically, unit members perform repetitive activities in doing their jobs.

_____ 8. There is a clearly defined body of knowledge of subject matter which can guide unit members in doing the work.

_____ 9. To a large extent, we can actually rely on established procedures and practices to do the work.

_____ 10. There is much variety to the duties performed, that is, the work requires many different tasks and skills.

R&D programs/projects often have performance objectives established in three major areas: Technical, Cost, and Schedule. In attempts to attain these objectives, a unit must attend to certain tasks or problems associated with each particular area. Consider the activities performed in your unit to achieve it's Technical, Cost and Schedule performance objectives.

In general, to what extent do you agree or disagree that the following are UNEXPECTED or NOVEL in your unit:

_____ 11. ...the TECHNICAL tasks or problems encountered.
_____ 12. ...the COST/BUDGETARY tasks or problems encountered.
_____ 13. ...the SCHEDULING related tasks or problems encountered.

1

Disagree	1	2	3	4	5	6
Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly

To what extent do you agree or disagree that the following can NOT be solved using a "straight-forward" method that is, a CREATIVE approach is often required.

____ 14. ...the TECHNICAL tasks or problems encountered.
____ 15. ...the COST BUDGETARY tasks or problems encountered.
____ 16. ...the SCHEDULING related tasks or problems encountered.

NATURE OF THE ENVIRONMENT

R&D organizational units must work within a set of demands and pressures resulting from factors or forces both within and outside the _____ . These demands may come from individuals, groups and other organizations.

Thinking of the environment outside your unit but WITHIN   , please indicate the extent that you agree or disagree with the following statements.

____ 17. There are frequent changes in the technical, economic, organizational, or political conditions within which directly affect your unit's work.

     18. These changes can usually be predicted or anticipated.

____ 19. The environment that your unit must contend with is diverse, that is, made up of many different individuals and groups within   .

____ 20. People can often point to prevailing ideas in their profession about the best methods or techniques to be used in their jobs. There are frequent changes in such ideas within   regarding your work.

     21. You know what to expect in your work-related dealings with people outside your unit but within   .

     22. Your unit is able to control or influence those factors within   that affect it's work.

     23. There are many different individuals or groups within   that effect or influence the work within your unit.

2

:	:	2	3	4	5	6
Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly

Thinking of the environment OUTSIDE BOTH your unit and   ,
please indicate the extent that you agree or disagree with the
following statements.

_____ 24. There are frequent changes in the technical, economic,
           organizational, or political conditions outside
                which directly affect your unit's work.

_____ 25. These changes can often be predicted or anticipated.

_____ 26. The environment outside of   that your
           must deal with is diverse, that is, made of   . many
           different individuals, groups and organiz   ns.

_____ 27. People can often point to prevailing ideas n their
           profession about the best methods or tech ic   to be
           used in their jobs. There are frequent cha   s in
           such ideas outside of   regarding your work.

_____ 28. You know what to expect in your work-related dealings
           with people outside of

_____ 29. Your unit is able to control or influence those
           factors outside of   that affect it's work.

_____ 30. There are many different individuals or groups
           outside of   that affect or influence the
           work within your unit.

UNIT STRUCTURE

Using the same scale, to what extent do you agree or disagree
with the following statements:

_____ 31. This unit serves only a select clientele i.e., customer
           or user either inside or outside the laboratory.

_____ 32. The personnel employed in this unit are very highly
           educated and trained.

_____ 33. Usually, written rules, written policies, and written
           procedures are relied on to perform the day-to-day
           work of this unit.

_____ 34. We always get orders or direction for our jobs from
           our superior.

3

	1	2	3	4	5	6
Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly

35. The work processes and methods used are unique to this unit.

____ 36. Several individuals have a say in making decisions in this unit.

____ 37. It is always necessary to go through offical channels when doing work or making decisions in this unit.

____ 38. For most situations, the rules and procedures are developed as the work progresses.

____ 39. If we feel we have the right approach to carrying out our job when dealing with a particular problem, we can usually go ahead without checking with our superior.

_____ 40. In this unit, each person has his her own responsibilities and duties that he she alone is expected to perform.

____ 41. There is a sharing of influence within the unit in making decisions.

____ 42. There are written rules and procedures for handling most of the problems which may arise in this unit.

43. People in this unit do NOT have clearly defined jobs.

____ 44. For the most part, we are not likely to openly express our feelings about our jobs.

45. The same written rules and procedures are followed in doing most of the work done in this unit.

____ 46. To make decisions in this unit, it is necessary to have written or recorded information prepared as the rules specify.

47. Our work requires each of us to perform many kinds of activities.

____ 48. We need to check with our superior before we do almost anything.

____ 49. Decisions are made at the "top" in this unit.

4

0	1	2	3	4	5	6
Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly

_____ 50. People are encouraged to speak their mind on the job even if it means disagreeing with our superior.

_____ 51. People in this unit always have the same areas of responsibility

_____ 52 This unit relies on written memos, reports, and forms to pass information back and forth within the unit to get the work done.

0	1	2	3	4	5	6
Never	Rarely	Once in a while	About half the time	Often	Almost Always	Always

INTER-UNIT DEPENDENCE

Please respond to the following statements using the above scale.

How often do you feel that YOUR work unit has to depend on people in other   units in order to get your work done in terms of the following items:

_____ 53. ...maintaining minimum QUALITY standards.
_____ 54. ...keeping your work on SCHEDULE.
_____ 55. ...meeting TECHNICAL performance specifications.
_____ 56. ...staying within BUDGET or COST limitations.

To what extent do you feel that OTHER units in   have to depend on your unit to get their work done in terms of the following items   (even if you're not sure, please indicate what you think is the case).

_____ 57. ...maintaining their minimum QUALITY standards.
_____ 58. ...keeping their work on SCHEDULE.
_____ 59. ...meeting their TECHNICAL performance specifications.
_____ 60. ...staying within their BUDGET or COST limitations.

5

0	1	2	3	4	5	6
Never	Rarely	Once in a while	About half the time	Often	Almost Always	Always

INTER-UNIT COORDINATION

The following 5 questions concern the methods that specify how units within _____ are to work together to achieve their objectives.

Using the above scale, to what extent do you feel the following methods are used to achieve COORDINATION between your unit and other units in _____ :

_____ 61. How frequently are there written rules or procedures used which specify how _____ units are to work together (for example, regulations or policy statements) ?

_____ 62. How frequently are written plans or schedules developed jointly by the units involved to coordinate their efforts ?

_____ 63. How frequently are individuals assigned to act as a liaison or "point of contact" between two units as part of his or her duties ?

_____ 64. How frequently are temporary teams or committees (such as, ad hoc groups or task forces), composed of members from the units involved, used to coordinate work ?

_____ 65. How frequently are "permanent" teams or organizations established within _____ composed of multiple units working together on some common effort (such as the project or matrix organization) ?

P L E A S E

C O N T I N U E

T O   N E X T   P A G E

6

	1	2	3	4	5	6
Never	Rarely	Once in a while	About half the time	Often	Almost Always	Always

COMMUNICATION SURVEY

The following questions are concerned with the WORK-RELATED communications you have with individuals within and outside your unit. These communications or contacts may occur directly in person, or indirectly, such as by telephone or in writing. Using the scale above, please respond to the following items by placing the appropriate number in the space provided.

Sometimes information may exist which we know about which would be helpful in performing our job, but is NOT READILY AVAILABLE to us because of the time, expense, or difficulty in obtaining it. In general, how frequently do you find this to be the case with the information YOU NEED FROM:

66. ...your immediate superior ?
67. ...members of your unit ?
68. ...others outside your unit but within   ?
69. ...others outside of   ?

To obtain the information required to do your job, how frequently is it IMPORTANT for you to have an open, effective, communication channel with each of the following sources:

70. ...your immediate superior ?
71. ...members of your unit ?
72. ...others outside your unit but within   ?
73. ...others outside of   ?

With some of the information you receive it may be necessary to go back and check on it's ACCURACY. How frequently is this the case with information you receive from each of the following sources:

74. ...your immediate superior ?
75. ...members of your unit ?
76. ...others outside your unit but within   ?
77. ...others outside of   ?

How frequently is it easy for you to get information from each of the following sources:

78. ...your immediate superior ?
79. ...members of your unit ?
80. ...others outside your unit but within   ?
81. ...others outside of   ?

.	.	2	1	4	5	6
Never	Rarely	Once in a while	About half the time	Often	Almost Always	Always

How frequently do the following sources have information you
need or would find useful in performing your job:

_____ 82. ...your immediate superior ?
_____ 83. ...members of your unit ?
_____ 84. ...others outside your unit but within   ?
_____ 85. ...others outside of   ?

At times we must gather a lot of information. some not directly
relevant. in order to do our job properly Other times we need
only a small amount because the information is very specific and
exactly what we require. In general. how frequently is the
information you receive sufficiently SPECIFIC from each of the
following sources:

_____ 86. ...your immediate superior ?
_____ 87. ...members of your unit ?
_____ 88. ...others outside your unit but within   ?
_____ 89. ...others outside of   ?

How frequently do you find that you are NOT receiving an adequate
amount of information to do your job from each of the following
sources:

_____ 90. ...your immediate superior ?
_____ 91. ...members of your unit ?
_____ 92. ...others outside your unit but within   ?
_____ 93. ...others outside of   ?

How frequently do you find it DIFFICULT to get information from
each of the following sources:

_____ 94. ...your immediate superior ?
_____ 95. ...members of your unit ?
_____ 96. ...others outside your unit but within   ?
_____ 97. ...others outside of   ?

At times we may be unsure whether to believe the information we
receive from a particular source because it may be UNRELIABLE.
How frequently is this the case for the information you obtain
from each of the following:

_____ 98. ...your immediate superior ?
_____ 99. ...members of your unit ?
_____ 100. ...others outside your unit but within   ?
_____ 101. ...others outside of   ?

0	1	2	3	4	5	6
Never	Rarely	Once in a while	About half the time	Often	Almost Always	Always

Sometimes the information we obtain may get right to the heart of the problem we are facing. Other times the information may be too general for our particular needs. How frequently do you receive RELEVANT information from each of the following sources:

_____ 102.   ...your immediate superior ?
_____ 103.   ...members of your unit ?
_____ 104.   ...others outside your unit but within   ?
_____ 105.   ...others outside of   ?

How frequently is the information you receive from each of the following sources of sufficient QUALITY to be useful in doing your work such as in problem-solving or decision-making):

_____ 106.   ...your immediate superior ?
_____ 107.   ...members of your unit ?
_____ 108.   ...others outside your unit but within   ?
_____ 109.   ...others outside of   ?

How frequently do you seem to receive MORE information than you can effectively use from each of the following sources:

_____ 110.   ...your immediate superior ?
_____ 111.   ...members of your unit ?
_____ 112.   ...others outside your unit but within   ?
_____ 113.   ...others outside of   ?

Considering the work-related communications you have with people with whom you come in contact, what percentage of your communication is with each of the following: note that this item is asking for your estimate - do NOT use the above scale for this item):

_____ 114.   ...your immediate superior ?
_____ 115.   ...members of your unit ?
_____ 116.   ...others outside your unit but within   ?
_____ 117.   ...others outside of   ?

100%   TOTAL

0	1	2	3	4	5	6
less than once a Month	once a Month	2-3 times a Month	Once a Week	2-4 times a Week	Once a Day	Several times a Day

The following items refer to the frequency that you seek or provide
Technical, Cost or Scheduling information. Please answer these
items using the scale at the top of the page.

How frequently do you SEEK information from each of the
following...

a. concerning TECHNICAL matters:
_____ 118. ...your immediate superior ?
_____ 119. ...members of your unit ?
_____ 120. ...others outside your unit but within   ?
_____ 121. ...others outside of   ?

b. concerning COST-BUDGETARY matters:
_____ 122. ...your immediate superior ?
_____ 123. ...members of your unit ?
_____ 124. ...others outside your unit but within   ?
_____ 125. ...others outside of   ?

c. concerning work SCHEDULING matters:
_____ 126. ...your immediate superior ?
_____ 127. ...members of your unit ?
_____ 128. ...others outside your unit but within   ?
_____ 129. ...others outside of   ?

How frequently do you PROVIDE information to each of the
following...

a. concerning TECHNICAL matters:
_____ 130. ...your immediate superior ?
_____ 131. ...members of your unit ?
_____ 132. ...others outside your unit but within   ?
_____ 133. ...others outside of   ?

b. concerning COST-BUDGETARY matters:
_____ 134. ...your immediate superior ?
_____ 135. ...members of your unit ?
_____ 136. ...others outside your unit but within   ?
_____ 137. ...others outside of   ?

c. concerning work SCHEDULING matters:
_____ 138. ...your immediate superior ?
_____ 139. ...members of your unit ?
_____ 140. ...others outside your unit but within   ?
_____ 141 ...others outside of   ?

BACKGROUND

_____ What is your sex ?   1. Male   2. Female

_____ What is your age ?

_____ How many years have you been with _____ ?

_____ How many years have you worked in this unit ?

_____ What was the last educational program you completed
or degree you received ?

        1. High School
        2. Associate (2 year) degree
        3. Bachelor degree
        4. Masters degree
        5. PhD.
        6. Post Doctoral
        7. Other (specify)

_____ In what field was your last degree ?

        0. Not Applicable
  1. Aero. Engineering   7. Mathematics
  2. Chem.   Eng   8. Biology
  3. Computer Eng.   9. Chemistry
  4. Electr. Eng.   10. Physics
  5. Indust. Eng.   11. Computer Science
  6. Mech.   Eng.   12. Materials Eng.
        13. Other (specify)

_____ Which term BEST describes your current position in
the organization?   please select one:
        1. Department Director
        2. Group Leader
        3. Senior Engineer/Scientist/Researcher
        3. Engineer/Scientist/Researcher
        4. Senior Technician/Researcher
        5. Technician
        6. other (specify)

_____ Which area of "R&D" BEST describes the work being
performed in your unit? please select only one:

        1. Basic Research
        2. Exploratory Development
        3. Advanced Development
        4. Engineering Development
        5. Other (specify)

In which phase of the Acquisition Process are most of
Programs/Projects your unit is working on ?

    0. Do Not Know
    1. Conceptual Phase
    2. Validation Phase
    3. Full Scale Development Phase
    4. Production Phase
    5. Other (specify)

Is the majority of your unit's work CLASSIFIED ?

    1. Yes
    2. No

Approximately what percentage of the technical work
for which your unit is responsible, contracted or
performed outside the unit ? (please select only one)

    0. none
    1. less than 25%
    2. 25 - 49%
    3. 50 - 75%
    4. more than 75%

How many different projects or contracts are you
currently involved with ? (please write in the number)

For an average MONTH, how many days do you travel
on business related matters ?   (select one)

    0. almost never
    1. less than 2 days
    2. 2-5 days
    3. 6-10 days
    4. 11-15 days
    5. more than 15 days

APPENDIX B

EVALUATOR SURVEY

UNIT EFFECTIVENESS QUESTIONNAIRE

This questionnaire is being used in support of research being sponsored by the Air Force Institute of Technology and Rensselaer Polytechnic Institute. You are being asked to complete this questionnaire for the unit identified on the following page. All responses to this questionnaire will remain STRICTLY CONFIDENTIAL and in no circumstance will you or an individual unit's be identified in the research report. By insuring anonymity for you as well as for your organization, the investigators are attempting to provide a means for you to respond with your true feelings.

Please complete this questionnaire for those units which you are familiar. It is extemely important that you answer all items in order for the questionnaire to be included in the analysis.

Your responses to this questionnaire are an ESSENTIAL part of this research study. Thank you for your participation.

Please select the phase test describes your position in the organization check one):

        _ 1. Technical Director
        _ 2. Associate Technical Director
       __ 3. Department Head
    ___ 4. Associate Department Head
       _ 5. Other specify

UNIT GROUP

Please assess the following characteristics concerned with the "technology" or "systems" development efforts currently being undertaken by the above unit. For each of the 6 items, please indicate your response by writing in the NUMBER you feel best describes that particular characteristic for the unit. To facilitate this process, each item has descriptions ranging from "poor" to "superior" that serve as benchmarks for you to consider in your evaluation. (Please Note: Substitute DoD for AF)

1	2	3	4	5	6	7	8	9
Disagree Strongly				Neutral				Agree Strongly

UNIT EFFECTIVENESS

Please use the above scale to respond to each of the following items, placing the appropriate number in the space provided.

To what extent do you agree or disagree with the following statements about this unit.

____ 7. Generally, the efforts made by people in this unit contribute to the overall goals of the organization.

____ 8. The people in this unit turn out high quality products or services.

____ 9. In the last 12 months, this unit has been able to complete, on time, it's planned milestones and activities.

____ 10. The people in this unit do NOT seem to get maximum output from the resources (money, time, and equipment) they have available. That is, they work inefficiently.

____ 11. The people in this unit anticipate problems that may come up in the future and prevent them from occuring or minimize their effects.

____ 12. For the most part, people are cooperative with and helpful to other people in the laboratory whom, through their work, they come in contact.

____ 13. The work performed by this unit meets or exceeds the technical objectives or standards set for it.

____ 14. When changes are made in the routines or procedures, people in this unit accept and adjust to these changes.

____ 15. When emergencies arise, such as a schedule being moved up, overloads are often caused for many people. This unit copes with these emergencies more readily and sucessfully than other units.

____ 16. Over the past year, this unit has been able to meet it's budget limitations or cost constraints.

APPENDIX C

SUMMARY OF PREVIOUS USAF RESEARCH

IN AREA OF R&D PROJECT MANAGEMENT

APPENDIX D

PATH ANALYSIS

Introduction

In the last few years techniques for causal inference from nonexperimental data (that is, data based on naturally accuring events) have emerged as important research tools within sociology, economics, and political sciences under such names as causal models, path analysis and structural equation models (Cook and Campbell, 1979). These techniques are often used in performing "confirmatory analysis" in the sense that these procedures are designed to evaluate the utility of causal hypotheses (or models) by testing the fit between a theoretical model and empirical data (James, Mulaik, and Brett, 1983). The emerging dominance of these techniques can be verified by consulting the contemporary theory-related empirical studies in sociology as well as methodological journals such as Sociological Methods and Research and Social Science Research (Cook and Campbell, 1979). Similarly, a number of conceptual models within the current management literature propose causal relationships among a number of variables. Such models include organizational design, motivation theory, and MIS implementation strategies. Many of these models remain conceptual in nature since they have not been

empirically assessed. Path analysis is basically a research method which employs regression analysis techniques to assess the consistency of empirical data to a conceptual or theoretic model. Thus, path analysis offers the management scientist a structured approach for examining and assessing various conceptual relationships or models within empirical settings, an essential component of the research process.

This appendix provides a brief introduction to the techniques of path analysis as used in the context of this study. For a more complete discussion causal inference techniques consult Wright (1934), Blalock (1971), Goldberger and Duncan (1973), Kerlinger and Pedhazur (1973), Duncan (1975), Heise (1975), Nie, Hull, Jenkins, Steinbrenner and Bent (1975), Cook and Campbell (1979), James Mulaik and Brett (1982), and Asher (1983). The following discussion of path analysis is primarily based upon Kerlinger and Pedhazur (1973), Nie, Hull, Jenkins, Steinbrenner and Bent (1975), and an empirical research study conducted by Noyes and Parker (1978).

Method

A path analysis technique was used to analyze the data collected in this study to examine the overall adequacy of the information

processing model of organizational design and effectiveness within the USAF R&D field setting. Path analysis is a method of examining the linear relationships, through a series of regression analyses, among a set of variables by assuming (1) a weak causal ordering among the variables, (e.g., based on a conceptual model), (2) the relationships among these variables are causally closed (Nie, Hull, Jenkins, Steinbrenner & Bent, 1975), and (3) the variables are empirically measured on an interval scale (Karlinger and Pedhazur, 1973). The basic assumptions of linear regression concerning the error terms are also in effect; that is, the error components are independently, identically and normally distributed, they have an expected value equal to zero, and a constant variance. Appropriate measures need to be built into the research methodology to ensure that these assumptions are justified. Such procedures include having independent measures for the variables and performing residual analysis on the regression equations.

Path analysis uses both path (causal) diagrams and sets of linear regression equations to represent a system of relationships among a set of variables, as shown in Figure 4.4 and Table 4.20, respectively. In path diagrams, assumptions about the causal ordering or direction of relationships are indicated by the use of one-way

arrows leading from each predictor variable to each "dependent" variable. Paths between variables are labeled with path coefficients, as shown in Figure 4.4. According to Duncan, the first subscript identifies the dependent variable and the second indicates the variable whose direct effect on the dependent variable is measured by the path coefficient.

An examination of the simple recursive equations for the model presented in Table 4.22 shows that unbiased estimates of the path coefficients can be derived by assuming that the error terms in each equation are uncorrelated with those of other equations and with all of the predictor variables that appear in their respective equations. This assumption is justifiable in this setting since each variable was independently measured. It is also customary to estimate path coefficients from latent variables (i.e., all residual causes) associated with X_i by $\sqrt{1 \cdot R^2}$, the effect of E_i, where the multiple R is that part of the regression equation in which X_i is the dependent variable and all casually prior variables are used as predictors (Nie, et. al., 1975).

The causal model shown in Figure 4.4 can be represented as a special case of general path analysis: one where there are no unmeasured variables (other than residual factors), the residuals are

uncorrelated, and each of the dependent variables is directly related to all variables preceding it in the casual sequence. In the model used here, path analysis equates to a series of conventional regression analyses. The path coefficients are simply the beta coefficients in the regression solutions. By following the SPSSX computing system which inverts the matrix of intercorrelations of the independent variables, the standard errors of the beta coefficients are automatically obtained (Duncan, 1966). This method of path analysis measures variables as deviations from their respective means, thus obtaining standardized beta values for the variables (or path) coefficients, which in the bivariate case is mathematically equivalent to a zero-order correlation coefficient (Jermier & Schriesheim, 1978). Therefore a path coefficient is equal to a zero-order correlation wherever a variable is considered to be dependent on a single cause and a residual (Kerlinger and Pedhazor, 1973). Path coefficients in the multivariate case, however, are mathematically equivalent to multiple partial correlations (Jermier & Schriesheim, 1978). However, the same principle applies in the multivariate regressions where the dependent variable is conceived to be dependent on more than one cause provided the causes are independent. Both bivariate and multivariate regressions appear in the equations of Table 4.22 for the model shown in Figure 4.4.

Path Analysis and Theory Testing

Several interpretations of the path coefficient values are commonly made in path analysis. First, the completeness of each relevant subsystem (or component of the model) may be assessed by examining the path coefficients from the latent (i.e. residual) variables (Nie, Hull, Jenkins, Steinbrenner & Bent, 1978). However, in sociological models where there are likely to be large numbers of extraneous influences on each variable, the calculated residual influences may reveal that a high percentage of the variation in each variable remains unexplained by the causal relations in the model.

Secondly, the total covariation between pairs of variables represented by r can be decomposed into causal and spurious components. Thus path analysis provides at least a partial test of the causal closure of bivariate relationships.

Third, the effects of any prior causal variable on any succeeding variable may be identified.[1] The effect coefficient (C_{ij})

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[1] The only relationship for which path analysis does not generate information beyond that contained in the bivariate correlation and the initial assumptions of the (general) model is the initiating structure or variable (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1978). In the first variable, nominal data can be incorporated into the model by using a "dummy" variable into the regression equation. The initiating variable for the casual model in this study is the R&D variable $(X_9$, which is nominal in nature with two major categories: research (technology expansion) and development (systems development); therefore, the dummy variable technique for developing regression equations can be used.)

measures the accompanying changes in X_i given a unit change in X_j while controlling for extraneous (residual) causes (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1978).

As previously mentioned, path analysis allows one to determine whether or not a pattern or correlations for a data set is consistent with a specific theoretic formulation (such as the Tushman/Nadler model). Kerlinger and Pedhazur (1973) point out that by using path coefficents it is possible to reproduce the correlation matrix (R) for all variables in the system and test the "goodness of fit" of a model to the empirical data. They note that as long as all variables are connected by paths and all path coefficients are employed, the R Matrix can be reproduced regardless of the causal model specified. However, the efficacy of path analysis for theory testing or development is in the ability to construct models where a minimum of path coefficients are needed to adequately reproduce the R Matrix. Deleting a path between two variable amounts to setting its path coefficient to zero, which implies that any correlation between the variables is due to indirect effects only. Through the deletion of paths, the research can offer a more parsimnious causal model for consideration, if the original R Matrix can be reproduced, or approximated (Kerlinger and Pedhazur, 1973).

Kerlinger and Pedhazur discuss two criteria for determining candidates for path deletion: statistical significance and meaningfulness. Since the path coefficients we are dealing with are equal to B's, testing the significance of a path coefficient is equivalent to testing the significance of the B within the regression equation. Thus, by adopting a prespecified level of statistical significance, path coefficients can be deleted from the model. However, when large sample sizes are used, extremely small path coefficients may be found to have statistical significance. To control for this situation, Kerlinger and Pedhazur suggest use of a "meaningfulness" criteria. Admittedly subjective, Land (1969) recommends that path coefficients less than .05 may be treated as not meaningful.

In terms of to what extent the R Matrix can adequately be approximated, Kerlinger and Pedhazur suggest that if discrepancies are less than 5% between the original and reproduced correlations, then *the more parsimonious model* which generated the new R Matrix should be considered tenable.

Note that this does not imply the theory or relationships are shown to be "true". Causal inference, for which path analysis is intended, only indicates whether or not the relations in the data are

consistent with the theory. For theory testing, path analysis provides an assessment of the consistency of the empirical data to the model. For theory development, path analysis can be used to determine meaningful and significant relationships existing within the data for modification or development of existing theory. Chapter 6 used path analysis in the sense of theory testing, that is an assessment of the Tushman/Nadler model. Chapter 7 uses path analysis in the sense of theory modification or development, by proposing a revised model based on relationships found within the data.

APPENDIX E

TABLES OF FACTOR MATRICES

Table E-1

Rotated Factor Matrix for Technology Variable Items*

Item	Factor 1	Factor 2
EXCEPT 1	.83	
EXCEPT 4	.80	
EXCEPT 5	.73	
EXCEPT 2	.72	.46
EXCEPT 3	.67	
ANAL 4		.85
ANAL 5	.38	.80
ANAL 2		.79
ANAL 3	.32	70
ANAL 1	.56	.64
Eigenvalue	5.29	1.35
Percent of Variance	52.9	13.5

*Factor loadiangs of ≤.3 not included.

Table E-2

Rotated Factor Matrix for Environmental Uncertainty Variable Items*

Item	Factor 1 (SSVSCD)	Factor 2 (PREDIC)
CHANGE3	.80	
CHANGE4	.78	
COMPLEX3	.78	
COMPLEX4	.78	
CONTROL2		.84
PREDICT4		.84
PREDICT3	.40	.53
Eigenvalue	2.93	1.50
Percent of Variance	41.8	21.4

*Factor Loadings of $\leq .3$ not included.

Table E-3

Rotated Factor Matrix for Inter-Unit Dependence Variable Items*

Item	Factor 1 (Othdep)	Factor 2 (Depoth)
OTHDEP1	.95	
OTHDEP3	.94	
OTHDEP2	93	
OTHDEP4	.79	.42
DEPOTH3		.89
DEPOTH1		.82
DEPOTH2		.81
DEPOTH4		.81
Eigenvalue	4.65	1.79
Percent of Variance	58.2	22.4

*Factor Loadings ≤ .3 not included.

Table E-4

Rotated Factor Matrix for Unit Structure Variable*

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
CENT3	83					
CENT6	78					
CENT5	72					
FORM2	.68	38				
FORM1		85				
FORM5		80				
FORM4		80				
CENT1	.36	.71				
CENT2			.85			
CENT4	45		.65			
IMPER2	.42		.64			
IMPER1				.82		
FORM7		.32		.47		
SPEC8					.81	
SPEC7					.71	-.34
FORM3		.34				.81
SPEC6	-.34	-.38			.37	.47
Eigenvalue	5.75	3.14	1.49	1.20	1.16	1.00
Percent of Variance	30.3	16.5	7.9	6.3	6.1	5.3

*Factor Loadings $< .3$ not included.

Table E-5

Factor Matrix for Coordination Variable Items

Item	Factor 1
COORD4	.84
COORD3	.82
COORD2	.75
COORD5	.65
COORD1	.52
Eigenvalue	2.63
Percent of Variance	52.6

Table E-6

Rotated Factor Matrix for Supervisor/Manager as Information Source

Item	Factor 1	Factor 2	Factor 3
DIFF1	.85		
RELIA1	.80		
EASY1	.73		
AVAIL1	.73		
ACCUR1	.64		
QUAL1	.60	.59	
RELE1	.56	.53	
NEED1		.88	
IMPORT1		.82	
SPECFIC1	.54	.64	
ADEQ1	-.66		.88
Eigenvalue	4.88	2.20	1.09
Percent of Variance	40.6	18.4	9.1

Factor Loadings $\leq .3$ not included

Table E-1

Rotated Factor Matrix for Unit Members as Information Source

Item	Factor 1	Factor 2	Factor 3
NEED2	.81		
IMPORT2	.80		
RELE2	.73	.33	
QUAL2	.72	.33	
SPECFIC2	.61	.37	
EASY2	.58	.43	
DIFF2	.33	.74	
ACCUR2		.71	
RELIA2	.41	.69	
AVAIL2		.54	
ADEQ2		0.58	.31
LOAD2			.93
Eigenvalue	4.32	1.99	1.09
Percent of Variance	36.0	16.5	9.1

Table E-8

Rotated Factor Matrix for Others in Organization as Information Source

Item	Factor 1	Factor 2	Factor 3
RELE3	.87		
QUAL3	.85		
SPECIFIC3	.75		
EASY3	.69		
DIFF3	.64	.48	-.33
AVAIL3	.46	.32	-.39
LOAD3	.32	-.73	
ADEQ3		-.67	
ACCUR3	.36	.65	
RELIA31	.52	.58	
IMPORT3			.87
NEED3		-.38	.57
Eigenvalue	4.02	2.45	1.20
Percent of Variance	33.5	20.4	10.0

Table E-9

Rotated Factor Matrix for Information Sources
External to Organization

Item	Factor 1	Factor 2	Factor 3	Factor 4
QUAL4	.91			
RELE4	.86			
SPECIFIC4	.77			
ACCUR4	.69	.80		
EASY4	.31	.70	.31	
AVAIL4		.70		
DIFF4	.52	.68		
RELIA4	.43	.65		-.31
IMPORT4			.89	
NEED4			.84	
LOAD4				.87
ADEQ4		-.36		.63
Eigenvalue	4.32	2.18	1.21	1.12
Percent of Variance	36.0	18.2	10.1	9.3

Table E-10

Factor Matrix for Unit Effectiveness Measure

Item	Factor 1
Technical	.89
Performance	.84
Unit Productivity	.80
Anticipate/Minimize Problems	.78
Schedule Performance	.78
Contribution to Organization Goals	.78
Adaptability	.72
Cooperation with Others	.72
Efficient Use of Resources	.66
Cost Performance	.62
Eigenvalue	5.79
Percent of Variance	57.9

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